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The Mechanical Engineer

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Edited by
WILLIAM H. FOWLER,
Wh. Sc., M.Inst.C.E.

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Electricity and Mysterious Fire Outbreaks.

CERTAIN outbreaks of fire that have occurred during recent years, and which subsequent investigation has failed to explain satisfactorily, though it has led to the suspicion that they were in some way due to the electric current in the buildings where they occurred, lead us to describe an incident that came a little time ago within our experience, and which it appears desirable should be made public, as it reveals a source of danger even on premises where the risk of fire, under normal conditions, is infinitesimal.

In the case in question, one of the principals of the firm, happening by accident to go into the basement of his premises, heard a slight crackling noise, but paid little attention to it, and was about to leave the basement shortly afterwards when his attention was drawn to a light in a room which he had a few minutes previously vacated, and, returning in order to ascertain the cause, found to his surprise that a gas pipe that was laid along the roof of the ceiling was blazing and the lead from the melting pipe falling on the floor, while the blaze was steadily creeping towards the meter. The alarm was at once given, and as a result of the prompt measures taken the outbreak was extinguished. A few minutes' delay, however, would have rendered these efforts futile, for the distance to the meter was so short that a large supply pipe would then have been communicated with, and it would have been impossible to get at the meter stop tap, while the flames would then have been in contact with an inflammable superstructure, and a hoist hole being a few feet away, the outbreak might then easily have extended to all the floors of the building. How the outbreak occurred became then a subject for enquiry. At first the affair seemed very mysterious, for there was no one in the room, nor was there a gas alight in the room, while the position of the pipe on the ceiling made its accidental ignition by any person impossible. It transpired,

however, as a result of investigation, that a very similar outbreak occurred at the same time on some adjoining premises, and by an almost fortuitous circumstance it also was discovered in time to prevent serious damage. This led to suspicion being laid in some way on the electric mains, though it should here be pointed out that in neither of the two cases was electricity distributed to the premises. How then, it may be asked, did the current find its way and lead to the ignition of the gas pipe? Careful inspection pointed to a possible, and we believe now, the true, explanation. The gas pipe was laid in both cases more or less parallel with the water service pipe, and at the point where it ignited it was actually in contact. Further enquiries convinced the owners that the current must have been a stray one from the corporation electric light and power mains which passed under the street outside, and that this, passing along the gas pipe, arced across into the water pipe as a better conductor at the point where it touched the gas pipe, and in so doing fused the gas pipe and ignited it. Complaints to the central station authorities led to enquiries being instituted by them, but these did not prove satisfactory to the owners of the premises, as the traction and lighting departments were involved, and those responsible appeared to be mainly concerned in repudiating individual responsibility, and the owners finally had to be content with the bare assertion that no leakage had been discovered, though this did not obviously square with the facts, but we mention the attitude taken, as it shows the difficulty of bringing home responsibility in these cases. That the outbreak occurred in the manner suggested there is no room for dispute, and it can easily be understood that if the occurrence had taken place in the night time when no one was on the premises they might have been so injured or destroyed as to leave no trace as to how the fire had been caused. The explanation is so simple and the origin one that may so easily be latent in other premises that it is desirable, at all events, that the public should be put on their guard against it. One precaution to be deduced from the incident we have described is obvious, viz., that the gas and water service pipes in a building where electricity is used, or powerful currents exist in the neighbourhood, should nowhere be placed in contact. Had the current leaked into the gas or water pipe alone it would, of course, in all probability, have found an outlet without danger. It was merely that the water pipe offered a better track where it came in contact with the gas pipe that it arced across, and in so doing fused the pipe and ignited the gas. It may be that some of our readers have met with somewhat similar experiences, and if they have we shall be glad to hear from them, so that the facts may be put on record.

METHODS OF ECONOMISING HEAT.

THERE was recently delivered, by Mr. C. R. Darling, before the Society of Arts, a series of three Cantor Lectures on the subject of "Methods of Economising Heat." In his first lecture Mr. Darling referred briefly to the sources of energy not yet tapped to any extent for commercial purposes—solar radiation, tidal energy, the internal heat of the earth, and interatomic energy and expressed the opinion that these sources would be utilised when fuel supplies became scarce. Dealing with the use of fuels in high-temperature operations, he pointed out that the products of combustion must leave the furnace at a temperature not less than that of the heated object, and that, unless the heat thus escaping could be utilised in a second operation, its loss was unavoidable. In this connection he observed that in the rotary cement kiln the heat required to produce a proper clinkering temperature could not all be utilised in other parts of the process, and that extension of the length of the kiln beyond a certain point did not remedy the loss. A plea was made for the co-operation of industries, so that the heat escaping from furnaces might be used in a second process, such as evaporation, resulting in a saving of heat and money. Turning to the question of steam-raising, he pointed out the economic and other advantages of careful stoking. In large coal-fired boilers there was now no need to produce smoke, unless an attempt was made to work them beyond their proper capacity. On the other hand, when small hand-fired furnaces were used, a certain amount of smoke was considered inevitable. The advantages of oil fuel for steam-raising, particularly on steamships, were next considered, and the saving effected by the use of economisers and feed-water heaters in connection with boilers explained. A demonstration was given of the Bonecourt system for the surface combustion of gases, which, applied to a steam boiler, gave a thermal efficiency of over 90 per cent.; and it was suggested that it might be found more economical in the future to extract the gas from coal and use it for steam-raising on this system, selling the valuable by-products, than to burn the coal directly.

In his second lecture the author dealt with heat engines, and pointed out that even with the best modern appliances only 16 per cent. of the heat of the fuel was converted into work in the steam engine, and 30 per cent. in the case of the internal-combustion engine. The superior thermal efficiency of the latter type was discounted by the greater cost of the fuel used. It was shown that the large quantity of heat escaping in the cooling water of a condenser or cylinder jacket could not be utilised in the engine itself, nor was it easy to conceive an economical application of this heat for a secondary purpose. The heat of exhaust steam and cylinder gases, however, was often used for evaporation, drying, and feed-water heating. The economy of using highly-superheated steam was touched upon. Mr. Bowen Cooke, of the London and North-western Railway, had, he stated, on certain types of passenger engines effected a saving of 25 per cent. in the coal bill when a superheater was used, and that after allowing for the cost of installing the superheaters and for depreciation a net saving was shown. This was the general experience of locomotive engineers, who were almost without exception introducing superheaters. Suggestions for the centralisation of power were given, and the advantages and difficulties were pointed out. He referred to one aspect of this question which was often overlooked by its advocates, namely, the ease with which a strike on the part of the workers at the central generating stations would paralyse the whole of the industries which received the power. The present system of working in individual units, although more wasteful of energy, had much to commend it. Dealing next with the prevention of radiation losses from hot surfaces, he expressed the opinion that a large quantity of the heat now allowed to escape from the exterior of metallurgical furnaces might be saved by the use of suitable insulating material. A calculation for an annealing furnace, of 480 sq. ft. superficial area working at 1,600° Fah., showed that the heat lost by radiation amounted to 336,000 B.Th.U. an hour, representing a loss of 3d. an hour, or £90 a year of 7,200 working hours, of which at least one-half might be saved by proper insulation. At higher working temperatures the radiation losses were much greater, and it was suggested that furnace insulation, hitherto neglected, was a matter worthy of immediate attention.

In his concluding lecture Mr. Darling dealt mainly with the heating of rooms and buildings. The percentage of avoidable waste of heat was, he said, greater in domestic than in commercial appliances, a fact which was attributable to the unscientific design of firegrates and ranges. The closed stove for burning anthracite coal was rapidly coming into favour, and was a cheap and efficient warming agent for rooms. With reference to gas fires, it was stated that in modern forms 75 per cent. of the heat generated was utilised in warming the room, and further advantages were cleanliness and ease of adjustment. Such fires did not, however, ventilate a room so efficiently as open coal fires, and the radiations were less satisfactory owing to the lower temperature (1,300° to 1,700° Fah.) and the nature of the firebrick surface heated by the flame. An improvement would result if the Méker burner, or Bonecourt flameless combustion, could be applied, as in either case the temperature would be higher; and a further advantage would be gained by the use of a rough, black material in place of the pieces of firebrick. Electric heaters possessed the advantage of cleanliness, but were more costly initially and in

working. The methods of heating buildings by hot-water and steam radiators were then described, and in conclusion the relative costs of heating by the various systems in London were given as follows: Open coal fire, 1; gas fire, 1·5; closed anthracite stove, 0·5; hot-water radiator, 0·35; and electricity, 6.

OVERHEAD LINES FOR ELECTRIC POWER TRANSMISSION.

A PAPER on this subject was read by Mr. T. Schontheil at a meeting of the Western Section of the Institution of Electrical Engineers recently held at Bristol. The author at the outset pointed out that the question of wayleave played a very important part in the cost of overhead transmission and that a compulsory modification of the veto possessed by local authorities and a modification of the present Board of Trade regulations was desirable. Light overhead lines in this country were usually carried on wooden poles of Norway fir, creosoted with 10lbs. of oil per cubic foot of timber. Creosoting was, he said, the most satisfactory process for preserving the timber against the ravages of damp and insects, provided the wood when treated was reasonably dry. For heavy lines A poles were preferable to single poles. Careful tests showed that an A pole, properly braced, would sustain a load in a direction across its two members nearly five times greater than would a single pole of the same diameter as one of the members of the A pole. A ratio of height to base of 8 to 1 for A poles, and a factor of safety of 10, with flexibility in the direction of the line, were desirable for all wooden poles.

Steel poles were usually constructed in tower form of either angles or tubes, as the main members, braced together in the form of a hollow square, by flat sections, which formed a lattice work. Such lattice poles had great mechanical strength, together with a certain amount of flexibility. Owing to the difficulty of properly protecting them from corrosion, they were open to considerable objection on that score. On the Continent iron poles of single channel section for straight lines, and two-channel sections bolted together for strain poles were being largely used. Such poles possessed the advantage of being easy to handle, and easy to keep in good condition, besides being much cheaper than the lattice type. Tubular steel poles, owing to their cost and the difficulty of keeping the interior free from corrosion, were seldom used for transmission lines. The reinforced concrete pole had not yet been used in England, but it seemed to have many points in its favour. It was easy to construct, and could, if necessary, be made on the site, with a consequent saving of the cost of transportation. At Oklahoma City, U.S.A., about a thousand concrete poles were in use for transmission lines. They were 30ft. long, and hexagonal in section, with a hollow centre 16in. diam. at the base and 17in. at the top, the walls being 2¾in. thick. Running through each pole were 12 ¼in. diam. twisted reinforcing rods at a tension of 11,000lbs. The weight of each pole was about 2,000lbs., and the cost 35s. A mixture of one part cement, two of sand, and three of crushed stone was employed in their manufacture. Another American concern, which had some 30 miles of high-voltage line, used poles 30ft. high, 6in. square at the top, and 9in. at the bottom. These poles were reinforced with six ½in. square high-carbon steel rods, extra short lengths being added to take the excessive strain near the ground.

The efficiency of any line depended chiefly on the ability of the insulators to withstand not only the conditions of service, but such increases of electrical and mechanical pressure as were likely to be met with. In this country, porcelain insulators were almost exclusively used. An insulator, consisting of several units linked together and known as the suspension type, was coming into very general use for high-tension lines.

Of conductors there were only two metals commonly used, *i.e.*, copper and aluminium. Alloys of copper, such as phosphor bronze, were stronger, but were not as good conductors; whichever was used, the most important consideration was its strength. The factor of safety required by the Board of Trade, of ten, was much too high, one or two, or at most three, being ample for copper and aluminium lines, but no conductor should be smaller than No. 6 S.W.G. The respective merits of the two metals resolved itself mainly into a matter of cost, and aluminium seemed to have all in its favour, the present prices representing a saving of about 35 per cent. in favour of the latter. To secure a continuity of supply it was often deemed advisable to run double the number of transmission lines actually required, either on the same pole or on a duplicate set. In the majority of cases, however, one line was quite sufficient to serve as a stand-by.

The question of earthing was most important, but was too often neglected or done in as cheap a manner as possible. Perhaps not the cheapest, but certainly the most reliable and efficient arrangement was to affix underneath the lowest cross-arm of each pole a small bracket carrying a reel insulator supporting a line of No. 8 gauge copper wire, this being run from one end of the line to the other. A similar-sized copper wire was fixed to project about 6in. above each pole roof and then led down the pole backwards and forwards along each cross-arm, under each insulator pin collar, and so to the main earth wire, which should be properly grounded at each third pole.

Guard wires or cradles, when used to prevent lines falling to the ground, were often a source of danger, and it was far better to run an extra length of conductor on separate insulators, placed as close as possible to the others, over roadways and crossings. The end of the extra conductor to be extended well beyond the extreme width of the roadway or crossing and bound to the main conductor for a length of 1ft. or so.

Accumulations of dust and dirt often gave rise to faults. If the line ran near collieries or railway lines, it was advisable to have the insulators washed and wiped occasionally. Insulator pins were often a common source of weakness. To guard against this they should be made of ample strength. Wooden pins were useless, as they soon burned through. Weak binding was to be avoided as a frequent source of trouble. Of all the forms of wire clasps designed, none was equal to binding wire properly applied and of sufficient size. The great advantage of binding wire was that if a conductor broke, no insulator pins in the immediate vicinity of the fracture were damaged, the conductor being allowed to slip through its bindings.

A frequent cause of failure was due, not to any weakness, but a punctured insulator causing a partial leak, and so generating sufficient heat to burn the conductor through. In this respect a decided advantage could be gained by metal bands around the insulators to assist in dissipating the heat. Pole troubles were not numerous, but wooden poles, if not properly treated, were sometimes attacked with wet rot. Replacing such poles was a costly matter, and occasioned much inconvenience and loss, owing to the fact that the line had to be kept "dead" whilst the work was going on. A remedy of some value would be found in cementing the poles from the bottom to about 3in. above the ground line, and leaving an annular space between pole and cement to about 5in. below the ground line, the space to be filled with bitumen or a similar material. Another method of guarding against rot was, when the poles had become firmly set, to make an opening 4in. to 5in. wide round each pole to a depth of 3ft or 4ft., and into such hole pour concrete, tamping it well in and finishing off the top with an inclined watershed a few inches above the ground level. Such a method not only prevented water collecting around the base of the pole, but gave it a neat appearance.

Wireless Telegraphy as an Aid to Rescue Work in Mines.—In a Blue Book on mines and quarries in the United Kingdom recently issued, reference is made to the possible use of wireless telegraphy in mines as an aid to rescue operations. Experiments in the North of England yielded a great measure of success in communication between the surface and a depth of 800ft.

Calendars for 1913. — Wall calendars for office use is a rather favourite method of advertising with some firms, and a considerable amount of artistic taste is displayed on some of them. The most striking amongst those we have received is one by the United States Metallic Packing Company, who for several years have displayed quite exceptional merit in the designs they have issued. The present one gives quite a striking imitation in white relief of Thorwaldsen's celebrated statue of Cupid and Psyche. Amongst others we beg to acknowledge, are wall calendars from the Baldwin Locomotive Works, J. Warrilow, Ltd., Birmingham, and a neat desk calendar from the St. Helen's Cable and Rubber Company, Ltd., Warrington.

TESTS OF WOOD, PAPER, AND STEEL PULLEYS.

In a recent issue of our American contemporary, "Power," Mr. H. A. Woodworth gives the following account of tests made in 1909 by Mr. E. D. Biggs and himself at the Purdue University, to determine the breaking strength of pulleys of different kinds with a view to disclosing their principal points of weakness.

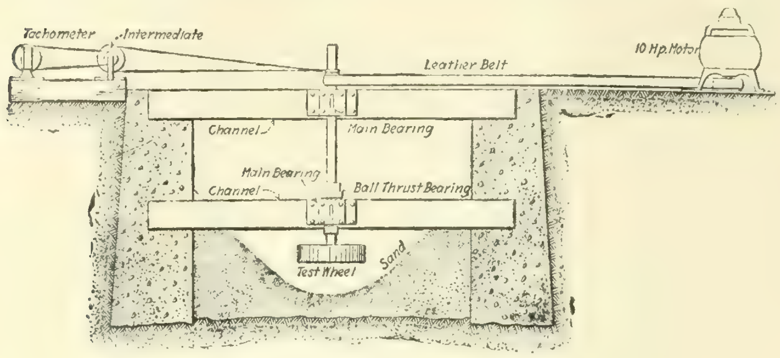


FIG. 1.—PIT FOR TESTING PULLEYS TO DESTRUCTION.

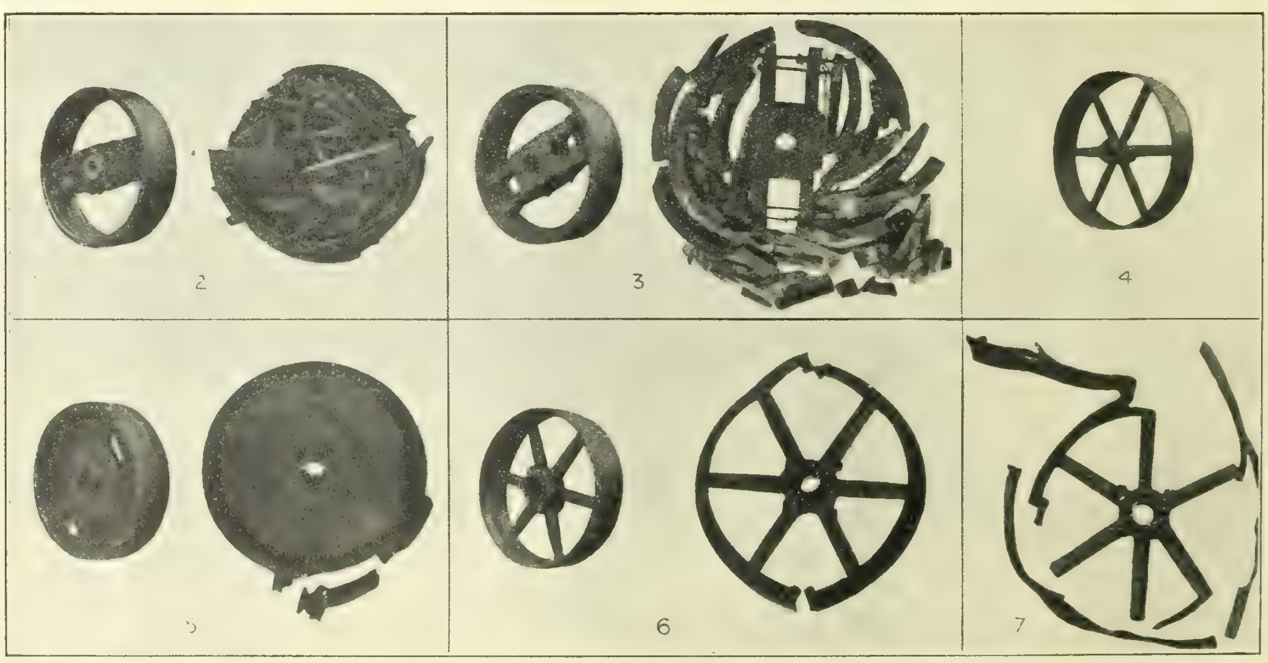
The object of the tests was to determine the relative bursting speeds of different types of pulleys, and, if possible, whether the weak points in each form of construction correspond with previous experiments. The condition of stress existing in the rim of a flywheel was first discussed by J. B. Stanwood (Trans., A.S.M.E., 1893). He showed theoretically that the bending due to centrifugal force might very materially reduce the bursting speed. This was later proved experimentally by Prof. C. H. Benjamin (Trans., A.S.M.E., 1899-1912), who tested model flywheels to destruction by revolving them in a bomb-proof case at varying speeds until they gave way. Benjamin's tests proved that joints between arms consisting of a pair of lugs connected by bolts were a great source of weakness. Further to prove these theories, and test the most improved designs of pulleys, a series of tests of 24in. wheels of cast iron, steel, wood, and paper were arranged for.

Fig. 1 shows the testing plant, which consisted of a cylindrical pit in which was placed a 3in. vertical shaft driven by a vertical motor. The shaft was supported in the centre of the pit by cast-iron bearings bolted to two horizontal channel irons, the ends of which were embedded in the concrete that formed the walls of the pit. The pit was 7ft. deep and 8½ft. diam. The shaft was belt-driven from a 10 h.p. variable-speed motor, which could be operated from 800 to 2,400 revs. per minute. Sand was piled around the inside of this pit to prevent flying pieces from coming in contact with the concrete wall when failure occurred. By this means the original fracture was obtained. The starting box, or controller, for varying the speed of the motor, was placed in a safe position some distance from the pit. The tachometer was placed on a heavy wooden block, about 4ft. from the pit. This block was embedded in the ground, with its top on a level with the top of the pit.

To determine the speed ratio of the main shaft to that of the tachometer a series of simultaneous readings were taken of the main shaft and tachometer, respectively, and from these data a curve was plotted with the tachometer readings as ordinates and the main shaft revolutions per minute as abscissas. This calibration curve was determined for every three or four pulleys tested, and proved to be a straight line through the origin upon which the results of all subsequent tests fell.

After balancing the pulley, photographing, weighing, and running the calibration curve, preparations were made to test the first wheel. This was placed on the shaft in the testing pit, and the pit was covered with planks to prevent any fragments from escaping. The wheel, which will be referred to hereafter as test wheel No. 1, was a two-arm solid-rim built-up type wooden flywheel, shown in Fig. 2, and weighed 29·37lbs. It was strengthened by six ½in. bolts, four of which were placed at the hub, and furnished means of clamping the flywheel to the shaft, the other two being placed one at each end through the continuous arm.

The test started at a very low speed, and as each new speed was obtained the operator stepped the motor to the next speed, using great caution to gradually accelerate the pulley. When the pointer indicated a speed of 2,720 revs. per minute, there was a noise like the report of a muffled powder explosion as the pulley let go. A fine débris of splinters, bolts, and nails, together with large pieces of the rim and flywheel arms, was found lying all over the bottom of the pit, showing the original disintegration fractures due to the excessive speed.



FIGS. 2 TO 7.—VARIOUS PULLEYS TESTED TO DESTRUCTION.

After the explosion the débris was gathered together, and assembled as nearly as could be, and a photograph, reproduced in Fig. 2, taken of it. The duration of this test was about 12 minutes. The peripheral speed at the time of fracture was 285ft. per second. The failure came very suddenly. The fracture was probably caused by one bolt in each end of the continuous arm giving out, due to the centrifugal force.

Tabulated data and results of the tests are shown in the accompanying table.

No. 2 was a duplicate of No. 1, and burst at a speed of 2,550 revs. per minute, or a peripheral speed of 267ft. per second. The whole rim was shattered, but the arms remained intact.

No. 3 was a split-rim built-up wooden pulley, the split being made at the ends of the arms, as shown in Fig. 3. This wheel was a duplicate of the first two wheels tested, except that the former two had solid rims. It burst at a speed of 2,210 revs. per minute, or a peripheral speed of 231·8ft. per second. The whole rim was shattered, but the arms remained as shown in Fig. 3. A close inspection reveals the uniformity in the strength of the split-rim wheel where the joint is at the end of the arms.

Wheels Nos. 4 to 10 inclusive were duplicates of No. 3. In all these wheels the fracture was due to weakened rims, caused by the holes made in them at the factory, in which were placed balancing weights. These weights, together with the weakened section, caused the failure. In some cases the bolts holding the arms to the two sections of the rim were considerably bent. In general the split-rim flywheel of this type has only 80 per cent. the strength of the same type with a solid rim. The results of the tests are shown in the table.

No. 11 was a solid cast-iron wheel, shown in Fig. 4. It had six arms, each having a cross-sectional area of 0·99 sq. in. It had a 6in. face and weighed 70·44lbs. This wheel was held on the shaft by two case-hardened set screws. Two attempts were made to break it, but each time the fuses burnt out at the switch. The maximum speed attained was 3,720 revs. per minute, or a peripheral speed of 389·4ft. per second.

No. 12 was a duplicate of No. 11. To avoid air resistance, sheet-iron discs were placed on each side of the wheel, and wired together through the spokes or arms. This did not avail anything, and the maximum speed obtained was 3,380 revs. per minute, or a peripheral speed of 353·8ft. per second. Further tests of these wheels were abandoned, owing to want of more power, as 15 h.p. proved insufficient.

No. 13 was a paper wheel having a solid rim and web, shown before and after being disintegrated in Fig. 5. This wheel was balanced in the web. The rim was held to the web by $\frac{5}{8}$in. wooden pins parallel to the axis of the shaft and approximately 4in. from centre to centre. The hub consisted of two heavy cast-iron plates bolted to opposite sides of the centre of the web forming the hub. This wheel burst at a speed of 2,820 revs. per minute, a peripheral speed of 295·2ft. per second. The fracture occurred as anticipated. A part of the rim 1ft. long flew off, separating itself into one large piece and several small fragments. The wooden pins connecting the rim to the web were broken off squarely. It is thought the fracture was due to the heaviness of the rim and the weakness of the pins connecting it to the web.

No. 14 was a duplicate of No. 13, and broke in the same manner. The fracture was presumably due to the same cause These two tests demonstrate the lack of strength in the rim of this type of wheel, which suggests a field for future improvement.

No. 15 was a pressed-steel split wheel; that is, it consisted of two sections or halves. Fig. 6 shows this wheel before and after fracture had occurred. In this type the rim was riveted to the arms, of which there were six. The sections of the rim were fastened together by a small flange which was riveted at each joint to the rim. A $\frac{1}{4}$in. bolt connecting these flanges held the two sections of the rim together. Each arm consisted of two flat pieces of iron $1\frac{3}{4}$in. by $\frac{3}{16}$in. in cross section, riveted one on each side of a seam on the inside of the rim. This type, having a very light rim, should have stood a very high speed, but it was seen that the rim was very weak at the joints.

The ends of each half of the rim where they were joined together were bent outward, thus rupturing the small flanges and bending the bolts that connected the two small flanges. The instant that a rupture was suspected the power was shut off, and when the motor stopped the rim was found bent out of shape, but not torn from the arms. The speed obtained was 2,240 revs. per minute, or a peripheral speed of 234·5ft. per second.

No. 16 was a duplicate of No. 15. The first fracture occurred in the same manner as with No. 15. Instead of shutting down the motor when the first distortion was suspected, it was continued until the greater part of the rim was torn away from the arms, which resulted in a loud crash. The rim was torn entirely away from four of the arms, but a part still remained attached to the other two arms. The metal was sheared out where the flanges were riveted to the rim, but the rim was sheared out where the arms were riveted to it. The speed was the same as for No. 15, being 2,240 revs. per minute, or a peripheral speed of 234·5ft. per second. In this case the bolt failed, as shown in Fig. 7. This illustration is interesting, as it shows clearly the bending action of the centrifugal force on the bolts, using the inner edge of the flange as a fulcrum.

The test of No. 15 was stopped at the critical moment. To have continued it would have resulted as shown in Fig. 6. This indicates how the joints failed. The joint opened like a clam shell, the bolts and flanges sheared out from the rim, and the arms remained uninjured. The joints in Fig. 6 display the shearing action, or cantilever effect, which in experiment 16 indicates that, as the bolts were strained and the joint loosened, one side of the joint was more affected by the centrifugal force than the other, causing a shearing action in the joint. These wheels burst at a much lower average speed than the paper, solid-wood, or even split-rim wooden wheels.

Data and Results of Tests on 24in. Pulleys.

1	2	3					4		5	6		7	8	9
		Rim					Arms			Bursting speed				
No. of Test	Kind of Material in pulleys	Style	Dia. in inches	Bdth. inches	Depth inches	Area sq. in.	No.	Area sq. in.	Weight in pounds	Rev. per min.	Peripheral speed = V ft. per sec.	Centrifugal tension $\frac{V^2}{\text{const.}}$	Character of fracture.	Remarks
1	Wood ..	Solid	24	6·25	1·62	10·15	2	14·4	29·37	2720	284·7	810·54	Completely broken.... .	
2	Wood ..	Solid	24	6·25	1·62	10·15	2	14·4	29·37	2550	266·9	712·35	Whole rim shattered ..	Arms remained
3	Wood	Two sections	24	6·5	1·78	11·6	2	8·25	29·67	2210	231·8	534·99	Whole rim shattered ..	Arms remained
4	Wood ..	Two sections	24	6·5	1·78	11·6	2	8·25	29·67	2110	220·8	487·53	Half of rim shattered ..	Arms and half of rim left on shaft
5	Wood ..	Two sections	24	6·5	1·78	11·6	2	8·25	28·81	2390	251·0	630·01	Whole rim shattered ..	Arms remained on shaft
6	Wood ..	Two sections	24	6·5	1·78	11·6	2	8·25	28·81	2430	254·3	646·68	Half of rim shattered ..	Arms and half of rim left on shaft
7	Wood ..	Two sections	24	6·5	1·78	11·6	2	8·25	28·81	2360	247	610·09	Half of rim shattered ..	Arms and half of rim left on shaft
8	Wood ..	Two sections	24	6·5	1·78	11·6	2	8·25	28·81	2420	253·3	641·61	Whole rim shattered ..	Arms remained slightly shattered.
9	Wood ..	Two sections	24	6·5	1·78	11·6	2	8·25	28·81	2570	258·5	668·22	Whole rim shattered ..	Arms remained
10	Wood ..	Two sections	24	6·5	1·78	11·6	2	8·25	28·81	2535	244·4	597·31	Half of rim shattered ..	Arms and half of rim left on shaft
11	Cast iron	Solid	24	6·0	0·406	2·44	6	0·99	70·44	3720	389·4	15,163·2	Not fractured	Not sufficient power
12	Cast iron	Solid	24	6·0	0·406	2·44	6	0·99	70·44	3380	353·8	12,517·4	Not fractured	Not sufficient power
13	Paper ..	Solid	24	6·0	1·75	10·5	Solid web 1·5 thick		77·37	2820	295·2	871·43	Portion of rim thrown off	Rim fastened to web by wooden pins
14	Paper ..	Solid	24	6·0	1·75	10·5	Solid web 1·5 thick		77·37	2930	306·7	940·65	Portion of rim thrown off	Rim fastened to web by wooden pins
15	Steel ..	Two sections	24	6·75	0·0625	0·422	6	0·656	41·75	2240	234·5	5,499·0	Flanges and bolts bent	Flanges riveted on to rim
16	Steel ..	Two sections	24	6·75	0·0625	0·422	6	0·656	41·75	2240	234·5	5,499·0	Flanges torn off .	Some rivets sheared

The test proves the source of weakness in the rim joint midway between the arms.

The stresses given in column 7 of the table were computed by the formula

$$\text{Stress per square inch of section, lb.} = \frac{V^2}{C}$$

where C is 100 for wood and paper and 10 for iron. The velocity V is the linear velocity of the centre of gravity of the section. The values worked out in the table show to what extent the strength is affected by bending. The above formula has been shown by Mr. Stanwood to represent approximately the tensile strength per square inch of rim section due to centrifugal force.

In every case the rim demonstrates the faulty design followed in modern practice. The surprisingly low bursting speed of the steel wheels proved conclusively that rim joints midway between the arms should be avoided, and these joints placed at the ends of the arms. The strength of the joint at the end of the arm is shown in the tests of the solid-rim wooden wheels, Nos. 1 and 2, as compared with the split-rim wheels, Nos. 3 to 10, inclusive. These were duplicates, except that one had a split rim and the other a solid rim.

These tests are the first ever made of paper, wood, or pressed-steel wheels. In fact, this is the first time the original fracture of a wheel tested to disintegration has been determined. In all previous tests the casing was so designed that flying particles struck it with such force that they were again broken, making it impossible to reassemble the pieces. It was due to the remote control that we were able to obtain the bursting speed so accurately.

Balancing wheels, by adding weight in the rim between the arms, produces a cantilever effect. In the iron wheels a piece of iron the size of a goose egg is sometimes riveted to the rim between the arms to balance it. At very high speeds the bending, due to the centrifugal force of this weight, causes disintegration. The wooden wheels are balanced by inserting iron lugs in the wooden cross-section of the rim, which decreases the cross-sectional effective area, weakening the rim, and failure occurs at this point. Wheels should be balanced by weights at the ends of the arms.

Conclusions. — (1) Balancing the wheels in the rim causes fracture at low speeds, and thereby lowers the factor of safety.

(2) Rim joints midway between arms are serious defects, and materially reduce the bursting speed.

(3) The solid-web-and-rim paper flywheel of the same type as tested (Figs. 7 and 8) will safely withstand a rim speed of 106ft. per second. By properly strengthening the rim the speed may be materially increased and a sufficient factor of safety retained.

(4) Wood flywheels with solid rim (Fig. 2) have an ample factor of safety at a rim speed of 90ft. per second, if the wood is of good quality and the same design is followed out. The speed of this wheel may be increased by using lighter bolts at the ends of the arms, as the weight of the bolts caused the original fracture in 90 per cent. of the wheels tested.

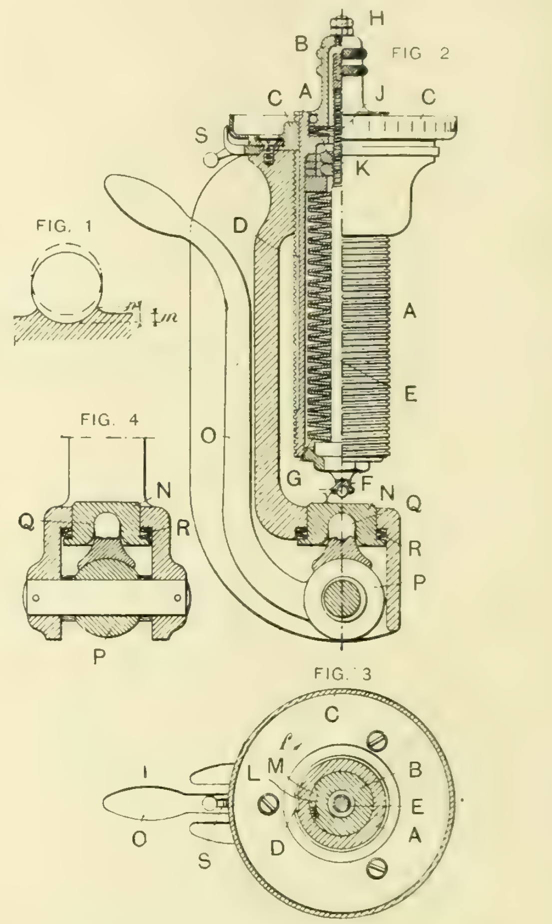
(5) Wood split wheels of the same design and material as shown in Fig. 3 will have a sufficient factor of safety at 72ft. per second rim speed. The design may be improved by using lighter bolts, and discontinuing the practice of balancing in the rim.

(6) The iron flywheels (Fig. 4), which were not tested to destruction, if of good iron and free from serious cooling strains will be safe at a rim speed of 120ft. per second. These wheels stood the best test of any of which there is record. The bending in the rim, due to centrifugal force, is so slight that it may be neglected in this type of wheel.

(7) Steel wheels of the split-rim type (Fig. 6) are unsafe at speeds above 80ft. per second. It has been noted that in various cases wheels of this type gave way through a solid rim, and without failure of the bolts, although the strength of the bolts was less than one-third that of the rim section, which shows that the strength of this joint, as usually calculated, has very little to do with the operative strength of the flywheel.

MACHINE FOR MEASURING DIRECTLY THE HARDNESS OF METALS.

WE illustrate herewith a design of machine for testing the hardness of metals, which has recently been patented by Mr. R. Guillery, 111, rue de Flandre, Paris. The machine is based on the principle, enunciated by Brinell, that the hardness of a piece of metal may be measured by the impression thereon of a ball of given diameter and weight. The ball is supported by an elastic cushion, the pressure of which is exactly set for a definite stroke of the cushion. This combination of elastic cushion and ball is carried by a guide screw threaded externally, so that it can be lowered more or less by rotating it, and carrying at its upper part a graduated plate, the angular displacements of which relatively to a pointer allow of direct reading of the hardness of the



MACHINE FOR MEASURING DIRECTLY THE HARDNESS OF METALS.

test piece. This hardness is measured by the impression of the ball in the metal to be tested. This impression is measured by the distance n (Fig. 1) which is greater than the true displacement m of the ball, for the latter produces a projection of the metal in the form of an annular lip of the height $n—m$. The plate is graduated in such a manner that it shows directly the value of m, which is a function of the displacement n of the ball. The deformation of the elastic cushion is produced by raising the support which carries the test piece, that at the same time causing the ball to penetrate into the metal and deforming the elastic cushion; this lifting of the support is performed by means of the lever mechanism described.

The machine (Figs. 2—4) comprises a frame, the upper part of which contains a female thread for the screw A, the latter being terminated by a milled button B. This screw can move vertically in an apertured circular plate C graduated empirically on its periphery; as the screw turns it rotates the plate with it, there being a groove D in the screw parallel to its axis engaging a lug on the inner periphery of the plate. The screw A is hollow and contains a rod E terminating at its lower part in a cup F in which is lodged the ball used for testing the hardness of the metal by the Brinell method. The rod E is subject to the vertical pressure of an elastic cushion consisting of Belleville washers G situated within the screw A

and exactly set to a determined weight. The adjustment of this cushion is made by means of the screw H. The milled button B when turned in the direction of the arrow *f*, Fig. 3, to press upon the spring member J interposed between the end of the button and the internal flange K of the screw A will cause this screw to turn in the same direction and descend, by reason of the friction set up between the parts J and K. As soon as the ball comes into contact with the specimen of metal to be tested, the friction will be insufficient to overcome the resistance then met with to further descent, and consequently the button will turn alone by itself within the screw A. When the button is turned in a direction reverse to that indicated by the arrow *f*, the slot and ball clutch shown in Figs. 2 and 3 will come into action, and by the wedging of the clutch ball L between the wall of the slot M formed in the button B and the inner wall of the screw A, this screw will be caused to turn in the same direction as the button and to rise. The screw may thus be caused either to descend and be stopped automatically as soon as the ball is in contact with the metal to be tested, or be completely raised. The elastic cushion G is flattened by the movement of the support N throughout the complete stroke of the lever O through the intermediary of the eccentric P keyed to the pivot of the lever and of the piece Q (Figs. 2 and 4). The support N is returned to normal position after removal of the pressure by a Belleville washer R. The machine is completed by a pointer S which slides with slight friction in the frame and is for the purpose of indicating relatively to the graduations on the plate C the coefficient of hardness of the test piece.

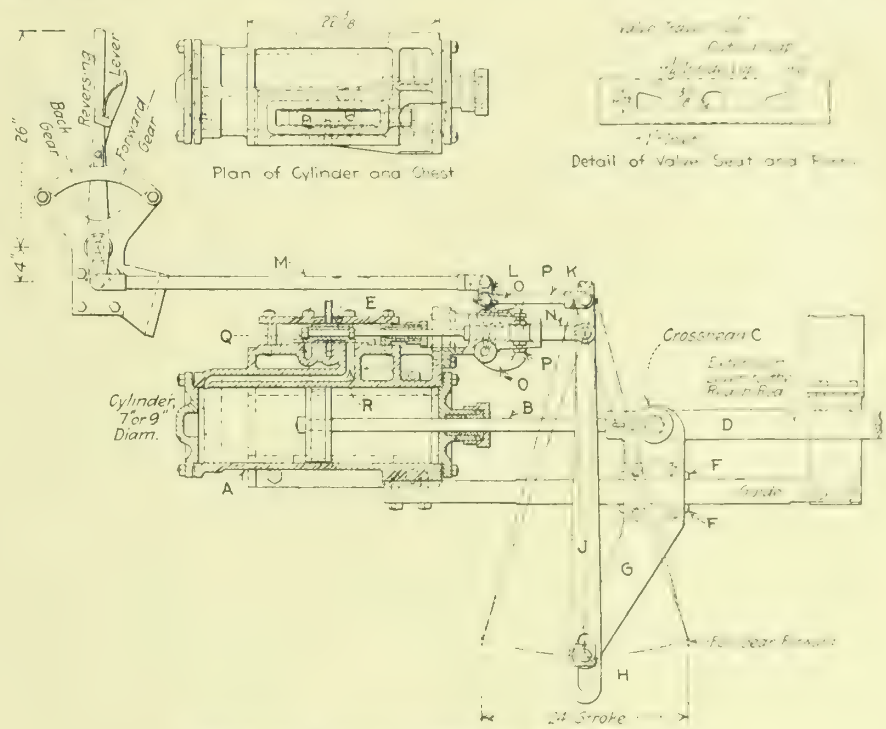
The machine operates in the following manner. The lever O being in the vertical position (Fig. 2) the test piece is placed on the support N. The button B is now turned to cause the micrometer screw A to descend until the ball comes into contact with the test piece. As soon as this happens the button turns in the screw without moving it. The pointer S is then moved until it is opposite the fiducial mark on the plate C and the lever O is operated to lift the support N and to cause the ball to penetrate into the metal; the lever O is then returned to its vertical position. The button B is now turned until the ball again comes into contact with the metal, this time entering the cavity previously formed; during this movement the screw A turns through an angle corresponding with the penetration of the ball. When the ball is home in the cavity in the metal the pointer S shows a graduation on plate C corresponding with the hardness of the metal. In this manner the hardness of the metal is ascertained directly without having to measure the impression of the ball in the metal.

THE RAGONNETT POWER-REVERSING GEAR.

THE power-reversing gear shown in the accompanying illustrations has been designed and patented by Mr. E. L. Ragonnett and is being adopted on a number of passenger locomotives in the United States. It was designed particularly with a view to facilitate the handling of Mallet duplex locomotives, since when reversing the engine or changing the point of cut-off it is necessary to operate both sets of valve gears simultaneously. This requires so much power that with hand-operated reversing mechanism the enginemen would not be likely to shift the cut-off more often than is absolutely necessary, with the result that the engine would not be worked in the most economical manner. This power gear has been applied also to large engines of ordinary classes. It is operated preferably by compressed air, although in several cases steam is used.

The gear consists of a horizontal cylinder A, whose piston rod B actuates a sliding crosshead C, which is connected to the reach rod by an extension lever D. The movements of the piston are controlled by a small lever and sector in the cab. The distribution of air (or steam) to the reversing cylinder is controlled by a plain slide valve E, arranged for outside admission. The crosshead gibs F are held in place by a plate or arm G, which carries a projecting stud H. This stud engages a slot in the floating lever J, the upper end of which is connected to the reversing lever in the cab by means of a link, rocker, and pipe rod (K L M). The floating lever is connected also to the stem of the slide valve by a rod N (near the top of the lever). The rocker L is provided with [illegible] arms O O, which strike the adjustable stops or setscrews P when the reversing lever reaches the limit of its movement on either side of its central position.

The reversing lever is locked at any desired position by a spring latch working in the toothed sector. When this lever is in its central position, the slide valve covers both admission ports. When the lever is moved into forward gear the floating lever J swings on the stud H so that the slide valve is moved forward and uncovers the rear port Q. Air is thus admitted to the front of the cylinder (the ports being crossed), and the piston moves to the rear. As it moves, the floating lever J swings on its upper end, and thus shifts the valve back (or to the left). When the link blocks have been shifted to position for the desired cut-off, as indicated by the position of the



RAGONNETT POWER REVERSING GEAR FOR LOCOMOTIVES.

reversing lever, the slide valve again closes the rear admission port (and both ports) and the movement of the piston ceases. For backward gear, the movements are in the opposite direction, and the forward admission port R is opened to admit air to the rear end of the cylinder. It will be seen that when the gear is set for any particular point of cut-off the slide valve is in its middle position. The exhaust or inside lap of the valve is materially greater than the outside lap (usually $\frac{1}{8}$in. for the former and $\frac{1}{32}$in. for the latter), so that air can be held on both sides of the piston simultaneously, thus locking the mechanism. The cylinder is oiled from a small lubricator in the cab.

The arrangement shown in the drawing is varied in some cases to suit particular arrangements of the valve gear. Thus the cylinder may be placed on the opposite side of the floating lever, and in such position that the bottom of this lever engages a stud on the crosshead, instead of on an extension arm as in the arrangement illustrated. We are indebted to "Engineering News" for the foregoing particulars of this gear.

Fatal Accident on an Oil Steamer.—An illustration of the possible dangers attending the use of oil as fuel is afforded in the case of an accident which occurred on the [illegible] in the stokehold of the oil steamer "San Edouard," built by Messrs. Swan, Hunter, & Wigham Richardson, at Neptune Works, Walker, Newcastle. The vessel it appears was being prepared for a trial trip when, without warning, a sheet of flame burst from one of the furnaces and filled the stokehold, enveloping nine men working there. All of the men were injured, three of whom have since died.

GAS AND OIL POWER PRACTICE IN EUROPE.*

BY H. J. K. FREYN.

THE development of the internal-combustion engine in Europe in the last year has been very marked, and great strides were made, especially by the Diesel engine. The unparalleled progress of this prime mover, due primarily to the expiration of the basic Diesel patents, has created a wave of enthusiasm, the crest of which swept Europe only a short time ago. To the careful observer signs of an ebbing of this wave are apparent, and more sober, more healthy views are gaining ground.

I was unable to find anywhere the 10,000 h.p. and 15,000 h.p. Diesel engine ships of which I had read in the current literature, and even Diesel engine enthusiasts do not believe that our modern leviathans will ever be propelled by Diesel engines. The largest single Diesel engine unit propelling any ship afloat develops not over 2,000 h.p., and there still remain many obstacles to be overcome before the single-acting multi-cylinder 4-cycle or 2-cycle Diesel engine on board ship is supplanted by the double-acting engine; vertical engines of the latter type are still in the experimental stage, and their future does not appear very promising on account of serious mechanical complication of scavenging pumps and multiplicity of scavenging valves in each cylinder head. The lack of the desired simplicity of these designs has prompted a number of inventors and manufacturers to experiment with the so-called "valveless" 2-cycle type, which presumably will become the large marine Diesel engine of the future. One valveless 2-cycle experimental engine of 260 h.p. is claimed to have shown an oil consumption of only 0·375lb. per indicated horse-power per hour, which at a mechanical efficiency of 60 per cent. would give 0·462lb. per brake horse-power per hour; in other words, the economy was as good as that of a regular 2-cycle engine with scavenging valves. The mean effective pressure obtained reached 125lbs. per square inch, which is truly remarkable in view of the extremely simple scavenging method employed.

Among the valveless 2-cycle engines, the Junkers oil engine has attracted a great deal of attention; it differs essentially from the regular type, and has reciprocal pistons and a three-throw crank shaft; the excellence of the form of combustion space is a great advantage of this engine, and gives it the distinction of being the best oil engine—at least, from a thermodynamic point of view. Practical experience alone will tell whether its unusual design and certain mechanical disadvantages will be offset by this advantageous feature. One of the foremost authorities in Europe very graphically characterised the Junkers engine as an oil engine built around a given perfect combustion chamber in contradistinction to all other Diesel engines where it is attempted to provide a satisfactory combustion space in an existing engine. Only a few smaller-size engines, mostly for marine propulsion and of the 2 or 3-cylinder vertical type, have been built abroad. The tandem arrangement of cylinders which results in the same number of crank efforts realised in ordinary single-cylinder double-acting 2-cycle engines has so far been applied only on two 800 h.p., 3-cylinder vertical engines to be fitted in a vessel of one of the largest steamship companies.

It is not certain that the large Diesel engine above 1,000 h.p. per unit will be an undisputed commercial success abroad, since the price of natural fuel oils steadily increases, largely limiting such engines to the use of tar oil. The horizontal double-acting 4-cycle M. A. N. Diesel engine in twin tandem arrangement of 1,600 to 2,000 b.h.p., which I had the privilege of examining at Halle, a./S., is a splendid piece of machinery, and operates apparently very satisfactorily on tar oil with a small addition of ignition oil. Although it is claimed that such an engine can be sold in Germany for from £6 to £6. 10s. per horse-power against £7 per horse-power for steam plant, it should be expected that the repair and maintenance cost will be much higher than even that of our present gas engines, on account of the high pressures and temperatures which are essential with the Diesel working principle and because of carbonisation at partial loads which can be prevented only by scrupulous cleanliness. In countries where the price of coal is high this engine type may have some importance, and a number of such engines of even larger unit capacity than the aforementioned one was sold in France and Russia, where fuel conditions are favourable for this type.

The small and medium Diesel engine in sizes of 40 h.p. or 50 h.p. in single-cylinder units up to about 600 h.p. in 4-cylinder units plays a vastly more important part abroad; it has unquestionably come to stay, and has reached a high degree of perfection which places it right in line with the corresponding steam or gas engine plant as far as reliability and cost of operation are concerned, and far ahead of its competitors when considered from the standpoint of fuel economy. It is amazing to note how many manufacturers of gas and steam engines abroad have taken up the manufacture of Diesel engines, because they found that the sale of suction gas producer plants and smaller steam engines has fallen off alarmingly within the last few years.

The reason is plain: The single-acting 4-cycle, single or multi-cylinder Diesel engine, but particularly the former, is comparatively simple in construction and operation. It does not require up-keep and attendance of boilers or gas producers, and its cost compared with that of steam or gas plant is reasonable. It can be installed in the basements of buildings below occupied dwellings, whereas in Europe boilers are not so permitted. One of the greatest advantages, however, is the fact that the actual fuel consumption of Diesel engines taken over long periods of operation does not materially exceed the guaranteed figures, whereas in gas producer and steam plants this excess is quite considerable. In a Diesel plant the human element, the skill of the operator, must have much less influence upon the fuel economy than in a steam or producer gas plant where everything depends upon the efficiency and intelligence of fireman and producer attendant.

The last two or three years have witnessed a remarkable development of the horizontal Diesel engine. Experience shows that the fuel consumption is only very little, if any, higher than that of vertical engines, but the horizontal type is decidedly preferred by the customer, not only on account of its lower cost, but particularly owing to its greater simplicity and better accessibility, using all kinds of fuels and installed for various purposes—for instance, for power transmission, for operating flour mills, for lighting factories, sanitoriums, office buildings, department stores, and for electricity works.

If conditions in Europe are not altogether favourable for the development of the large Diesel engine, they are much less so in this country. The price of oil fuel in any locality must be considered in connection with the prevailing coal price to determine whether a Diesel engine installation is economically efficient or wasteful. Cheap oil fuel will favour the Diesel engine only where coal is very expensive, whereas high oil and low coal prices will exclude it. Our fuel cost is not only lower and our labour cost much higher than in Europe, but the quality of our mechanical labour is not so excellent, and thus the fuel cost plays a much less important rôle in the total cost of power than the items into which labour largely enters, whereas the lower standard of manufacture and especially of maintenance favours the use of simple, although less economical machinery. With the variety of conditions which prevail in this vast country, however, a large field of usefulness of the smaller and medium-size Diesel engine is assured.

To what importance the use of tar oil has grown on the Continent can be judged from the fact that France has to rely almost exclusively on the use of this Diesel engine fuel, on account of the very high import duty on natural oils. In Germany a number of collieries have combined to form a company for the utilisation of tar. This company operates a large factory at Meiderich, where, at present, over 300,000 tons of tar a year is distilled, producing over 80,000 tons of tar oil. This is contracted for in larger quantities at a price of approximately 50s. per ton. With the tremendous increase in demand it is expected that before long this one factory alone will have a capacity of handling one million tons of tar per year, producing 300,000 tons of tar oil.

It is estimated that the total world production of coal tar oil is even now in the neighbourhood of 1,000,000 tons

* Abstract of address delivered before the gas power section of the American Society of Mechanical Engineers, December 4th, 1912.

per annum, and since the recognition that coal is too valuable a fuel to be wasted in our present-day furnaces is spreading more and more, the number of by-product coke oven and by-product gas producer plants will steadily increase, so that the total production of tar oil is certain soon to double and treble, adding to the supply of natural liquid fuels an artificial product which will by legitimate competition prevent the price of the former from going sky high.

The heat value of tar oil is over 17,000 B.T.U. per pound, and its consumption in the Diesel engine is, therefore, not very much higher than that of natural oil, varying now from 0·491b. to 0·461b. per brake horse-power hour, according to the size of the engine. The operation of medium-size Diesel engines on tar oil, especially of those above 50 h.p. per cylinder and with open fuel injection nozzle, is satisfactory. For smaller engines the addition of a so-called ignition oil is necessary, which fact somewhat complicates these engines.

Renewed activity is noticeable abroad in the matter of designing an adequate gas turbine, and I noticed that much interest is taken in this question by the most prominent manufacturing concerns in Europe. The foremost authorities abroad are convinced that the gas turbine will soon come to stay, and, while this really is not an extraordinary prophecy in view of the universal tendency towards revolving high-speed machinery, the statement would seem warranted that whenever the time of the gas and oil turbine does come, it will nothing short of revolutionise power production in the large steel centres and wherever natural fuel oils abound in this country.

The apparently inexhaustive supply of cheap coals, lignites, and peat, and especially of crude oil, together with the conditions of our labour supply, make the future of the gas turbine in the United States much more promising than in European countries. As mentioned before, we do not possess as high a class of labour as Germany, for instance, where the education of centuries has resulted in a quality of mechanical labour unsurpassed for manufacturing and taking care of thermally economical but mechanically rather complicated machinery. The tendency, so apparent in this country, to invest money with a view of immediate returns, a tendency demanding primarily cheap and reliable machinery, and concerned in a considerably less measure in the question of high fuel economy, will be favourable to the introduction of the gas turbine.

The gas turbine is destined to bridge over the chasm between the gas engine and the steam turbine, if after proper development it should eventually even just approach the economy of the gas engine, for it shares with the steam turbine the advantages of low cost, large unit capacity, reduced unit weight, small floor space, high speed and simplicity of operation and maintenance, whereas its better thermal efficiency will make it a serious competitor in plants where gas engines are now used. A large experimental gas turbine in Germany is operating splendidly, mechanically speaking, although the problem of satisfactory thermal efficiency still remains to be solved.

The use of the so-called industrial waste gases has progressed considerably. The four most prominent manufacturers in Germany alone are now building large gas engines for blast furnace and steel works at the rate of 120 per year and a number of twin tandem engines of 5,000 b.h.p. operating very satisfactorily on rich coke oven gas can now be seen in German coking plants. The splendid results obtained with gas blowing engines in Germany have prevented the turbo-blower from getting a firm foothold in that country, although its use in France, England, and Russia is steadily increasing. Blast furnace gas engines for blowing and electric power purposes and even for operating rolling mills, are to-day the standard equipment for old and new plants, even where coal prices are low.

Within the last two years the use of coke oven gas for producing electric power by gas engines has greatly increased, and after overcoming the many earlier difficulties the coke oven gas engine is to-day just as safe and reliable as the blast furnace gas engine. These difficulties arose principally from over-rating the engines, and from sulphur in the engine gas. Since the reasons for the trouble were recognised, the causes or their consequences are now avoided, so that in a number of plants sulphur of considerably over one grain per cubic foot of gas is very successfully handled in coke oven gas engines if the proper precautions are taken

The most prominent gas engine builders are now governing their engines on a simple combination quantity-quality regulation principle. The valve gear has been much simplified by all manufacturers, resulting not only in a reduction of the cost of manufacture, but also of operation of these engines, and gas engine prices are, generally speaking, lower than they ever were before. The gas cylinders, after a few unsatisfactory attempts to use steel castings, are invariably made of cast iron, and, with the exception of a few types, they are cast in one piece with integral water jacket. The gas cylinders are often provided with hard cast-iron liners. The cracking of gas cylinders, which formerly occurred altogether too frequently after a short time of operation, is now much reduced by proper design, selected material, and better pouring methods.

Experience has taught that the life of a gas cylinder can be materially increased if the water jackets are thoroughly cleaned from all scale and muddy deposit at regular intervals of four to eight weeks, depending upon the character of the cooling water used. This matter is of the greatest importance and should be heeded more than it is in this country. It was found by experiment that the average temperature of the cylinder wall increases at an amazing rate with even a very thin layer of scale forming in the water jacket, and in certain plants, with hard cooling water acid and wire brushes are resorted to from time to time to take the accumulated scale from the cylinder walls. It has been found that frequent shutting down and starting of gas engines shortened the life of the cylinders materially if the engines were allowed to cool off too much during shut-downs. The average life of a gas cylinder in the large steel plants in Germany is pretty generally reckoned to be five to six years. This is accepted as a matter of course and the expense incurred by replacement is simply distributed over this number of years in the cost figures.

The cost of producing electric power in German blast furnaces and steel plants is about 11s. per 1,000 kw.-hr., comprising 5s. in the raw blast furnace gas and including cost of gas cleaning, cost of labour, repairs and supplies of all kinds, but without interest and depreciation on the money invested. This figure applies on an annual output of about 100,000,000 kw.-hr., and a use factor of approximately 60 per cent.

The gas pistons are generally ribless iron castings, although for large engines steel cast is used. One concern has recently introduced for blast furnace gas engines one-piece solid, non-cooled forged steel pistons. The piston rods are now usually made of open-hearth steel of about 100,000lbs. tensile strength, uncambered, and their diameter is approximately 26 per cent. of the diameter of the gas cylinders. A variety of piston rod coupling designs is used, but the threaded connection enjoys the best reputation. It is noteworthy that crossheads are made of forged nickel steel. No uniformity of design can be claimed for piston rod packings, but they invariably consist of single or double sectional cast-iron packing rings pressed against the rod by garter springs and separated by solid one-piece rings forming 12 to 14 chambers. It is universally claimed that the clearances of the ring sections must be reduced to the possible minimum. The exhaust valves are made of forged steel or of Durana metal, and are now almost exclusively of the non-cooled mushroom type. Some builders, however, still prefer water-cooled exhaust valves for coke oven gas engines.

The progress of the large gas engine in Europe has been accompanied by great improvements in the method of purifying blast furnace gas. One of these new methods works on the principle of filtering the gas in a perfectly dry condition, so that no water is required save that necessary to cool the engine gas to atmospheric temperature. The filtering is achieved by means of Beth filter bags, which are made of special fabric and suspended vertically in several air-tight compartments. The raw blast furnace gas coming from the furnace at high temperature is first cooled by radiation to about dew point (around 130° Fah.) and thereupon superheated approximately 20° to 30° by using any available source of heat, such as waste heat from the gas engines, exhaust steam or even the sensible heat of the raw blast furnace gas itself. By cooling the gas a large amount of moisture is

removed and the scorching or burning of the filter bags prevented, whereas the subsequent superheating avoids condensation of the remaining vapour and clogging of the bags.

The raw gas under the action of a fan passes from the inside to the outside of the filter bags, depositing all impurities on the surface. The layer of dust naturally increases continually and would eventually render the bags impenetrable, were it not for an automatic mechanism which in a fashion, similar to that used in flour mills, shakes the bags at regular intervals of about 4 minutes and causes the dust to drop off. Simultaneously the compartment which is to be cleaned is automatically separated from the others, and the direction of gas current reversed; the purified gas surrounding the filter bags now enters the latter, opening the pores of the filter material, which were previously closed up by the passing dirty gas current. The dust shaken off the filter bags falls into a receptacle, from which it is removed in a perfectly dry condition.

Two experimental filter plants installed at Halberger, Huette and Duedelingen, have capacities of about 10,000 cub. ft. and 14,000 cub. ft. of gas per minute, and clean the gas for gas engines only. It is claimed that the [illegible] consumption is 2·5 to 3 times lower than that of [illegible] fans and Theisen washers, that the water consumption is only one-fifth to one-sixth of the corresponding requirements of wet-cleaning plants, and that the dust contents in the purified gas is below 0·0004 grain per cubic foot, or 15 to 30 times lower than in the purified gas obtained with the older wet-cleaning apparatus. The cost of operation is furthermore claimed to be much lower and the cost of installation only a little, if any, higher.

On the strength of the satisfactory results obtained, many blast-furnace plants in the Minette district, and even in Westphalia, have decided to install gas filtering plants, varying in capacity from 17,500 cub. ft. to 140,000 cub. ft. of gas per minute. One manufacturing concern alone, which acquired the rights for Germany, had in the month of July orders for installations for 21 plants, with a total capacity of 825,000 cub. ft. of gas per minute.

The other new system of gas cleaning makes use of the "disintegrator" principle; two well-known concerns in Germany, specialising in gas-washing apparatus, have developed this system on somewhat different lines, and one of them claims to have on hand orders for disintegrator gas washers capable of purifying 1,750,000 cub. ft. of gas per minute. One machine only is used for preliminary purification of boiler and stove gas from 2 to 3 grains per cubic foot to 0·088 to 0·175 grain of dust per cubic foot, with a water consumption of only 10 galls. and a power consumption not exceeding 0·072 h.p. per 1,000 cub. ft.; for gas engine purposes two disintegrators are placed in tandem which causes the power consumption to increase to 0·13 h.p., the water consumption to 18 galls. per 1,000 cub. ft., whereas the amount of dust in the gas drops to 0·0044 to 0·0088 grain per cubic foot.

The days of the wasteful bee-hive coke oven are fortunately past, and the highly economical by-product coke oven is gradually taking its place. The manufacture of coke entails the accumulation of large quantities of coke breeze, which cannot always easily be disposed of. Successful attempts were recently made in Europe to gasify this coke dust in special gas producers. One system operates with liquid slag very much on the order of a blastfurnace, whereas the other adapts a well-known European producer design to the special requirements of gasification of very fine fuels. In a number of European blastfurnace and coke-oven plants this coke breeze will be gasified in such producers, and the resulting gas of about 150 B.T.U. per cubic foot admixed to blastfurnace gas to increase its quantity and improve its quality.

Mixtures of industrial gases are used more and more for metallurgical and power purposes abroad; in one plant in England a mixture of blastfurnace and coke-oven gas is used for all heating purposes and to operate gas engines. At first glance it may seem difficult to obtain a sufficiently uniform mixture of two gases so different in specific gravity, but experience has shown that modern blastfurnace gas washers of the revolving type, such as fans, Theisen washers, and disintegrators are splendidly adapted for this purpose, and that changes in the quality and heat value of the mixed gas of even considerable magnitude do not seriously affect the operation of gas engines.

Another very interesting novelty of perhaps great importance for future gas engine application is in operation, namely, a system of overloading 4-cycle gas engines 25 to 35 per cent. of their normal capacity. The method devised and patented by one of the foremost gas engine manufacturers in Germany, and which creates an almost perfect analogy with the condensing plant of steam engines, consists in scavenging ordinary 4-cycle gas engines and introducing the fresh mixture under a pressure somewhat higher than atmospheric. This is achieved by raising the pressure of the combustion air and gas in turbo-blowers to a gauge pressure of a few inches of mercury and by scavenging the spent gases of the previous power stroke with a blast of this air, subsequently introducing gas and air under slight pressure into the combustion chamber. By utilising the waste heat of the gas engines for raising steam in suitable waste-heat boilers and driving steam turbines direct connected to the turbo-blowers, the power requirements of the auxiliaries can amply be supplied without resorting to outside sources of power, nor detracting from the increased output of the gas engine generator.

An overload of 35 per cent. was attained without raising the initial pressure—an important point—and without appreciable increase of the heat absorbed by the cooling water; the thermal efficiency of the scavenged engine was found to be somewhat, and the mechanical efficiency considerably better than that of the non-scavenged engine.

In another steel plant two tandem engines of 1,360 kw. or 2,000 b.h.p., normal rating (at 65lbs. mean effective pressure), which were provided with generators of 1,700 kw. capacity in anticipation of the overload scheme, can carry loads of 1,800 kw. to 2,000 kw. Before the changes were made in April, 1912, the average kilowatt output per engine in 12 hours as ascertained from the log-book was 13,000 kw.-hours, but since installing the scavenging plant the average output was raised to 18,000 kw.-hours and 20,000 kw.-hours in a 12-hour run, corresponding to an average increase of approximately 40 per cent.

Regarding the financial aspect of the matter, it can be shown that the capacity of an existing gas engine plant can be increased 30 per cent., provided the generators are large enough, at a considerable saving compared with the cost of providing for this increase in capacity by installing additional non-scavenged units.

The technical press has been rather silent during the last year regarding the Humphrey pump, but according to reliable information this is by no means an indication that this gas pump has passed out of existence; on the contrary, one of the largest concerns in Germany is devoting much time and effort on experiments to generate electric power with such a pump at its factory, and a 40,000,000 galls. pump will be installed in England on which a coal consumption of 1lb. per effective pump horse-power was guaranteed.

Examination of Engine Drivers. — Colonel Yorke, in his report on the railway disaster at Ditton Junction, on September 17th, when 15 persons were killed, some being burned, and 30 others injured, attributes the derailment and all that followed to the misreading of the signals by the driver, consequent on his lack of familiarity with the road, and considers that the engine was not efficiently manned for work upon such a busy section. The real cause of the disaster was, in his opinion, due to the lack of an adequate system of ascertaining and testing a driver's knowledge of the road, and he suggested that a responsible officer from head-quarters should be appointed as inspector for the purpose of examining, and if necessary testing, drivers in their knowledge of the road. The burning of the wreckage and all the distressing circumstances connected therewith raised once more the question of the use of gas for the lighting of railway carriages. So far as safety is concerned there can, the inspector states, "hardly exist in anyone's mind a doubt that electricity is the better, and I think the railway companies would be wise to recognise this fact and adopt electricity as the standard illuminant on all their main line trains before they are compelled to do so by the pressure of public opinion."

HEATING WATER BY ELECTRICITY.

ALTHOUGH electric heating of water is costly as compared with coal and gas, there are certain advantages in the way of cleanliness, convenience, and absence of smell and noxious fumes, that recommend its adoption under appropriate conditions, and where cost is a secondary consideration. At the present time there are quite a number of designs of electric water heaters on the market, several of which are described

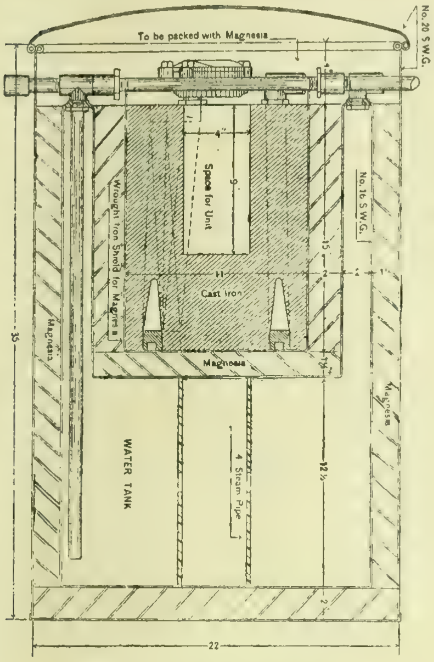


FIG. 1.—THEROL HEATER.

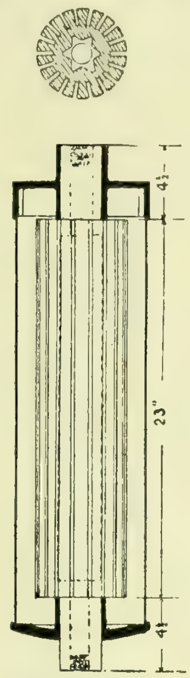


FIG. 2.—BELENUS ELECTRIC BOILER.

by Mr. A. H. Bridge in a recent issue of the "Electrical Review and Western Electrician," as follows:—

The first system placed on the market was known as the "Therol" system, and was introduced by Messrs. Spagnoletti, Ltd., London; the principal feature of this ingenious device was the use of a block of iron to store the heat. The block was cast around a coiled pipe, and was thoroughly well lagged with heat-insulating material, so that an efficiency well over 90 per cent. was attained, with an average wait of eight hours, that is, with an interval of eight hours between the storing and the utilisation of the heat. The advantage of iron was, of course, that it could be raised to a red heat, if necessary, without injury. The efficiency was greatly improved by enclosing the storage block within, but insulated from, a water jacket, which trapped and retained the bulk of the heat which escaped through the lagging. The construction of the apparatus is shown in Fig. 1, which is a vertical cross-sectional elevation of the Therol heater, and is self-explanatory. An important feature of the device is a mixing tap, which enables cold water to be drawn from the main simultaneously with the hot water which passes through the heater from the jacket; thus water of any desired temperature from cold to boiling can be drawn off. The heater illustrated, consuming 200 watts, and taking in water at 50° Fah., gives 25 galls. of water per day at a temperature of 110° Fah.—the temperature of a very hot bath. Smaller quantities can of course be drawn off at higher temperatures, and larger quantities at lower temperatures. The current is left on night and day, and as it cannot exceed a fixed amount, no meter is necessary; the daily consumption is 4·8 kilowatt-hours. In the latest patterns the iron block is cored, with screw plugs at the ends, which enable the block to be drilled out again if the passages become choked with deposit from the water, as frequently happened with the older type. The heating units are made to consume from 75 to 1,000 watts, for different sizes and outputs.

Another storage device is that recently introduced by A. Rittershausen, in which the water itself is heated; the tank, therefore, has to be large enough to hold the whole of the water to be heated, whereas the Therol apparatus, which stores heat at a higher temperature, and heats the water during its passage through the iron storage block, need not be so large. In the Rittershausen apparatus the tank is enclosed in a non-conducting jacket 8in. thick, and the water is admitted to the tank at the lowest point, under a perforated diaphragm, which prevents eddies which would cause the incoming water to mix with the hot water. The heating element is immersed in the water, near the bottom, and is surrounded by a circulating tube, which causes the water to rise past the heating element in a steady current to the top of the tank. Thus the hottest water forms a layer there, and as the outlet pipe is attached to the top of the tank, a supply of hot water is quickly available directly the heater is switched on. If the water is not drawn off, it is displaced by the circulation and slowly sinks, with hotter water above it, until the whole of the tank is full of hot water, when a relay actuated by a thermometer cuts off the supply current. It will be seen (Fig. 3) that the outlet pipe is bent downwards when it leaves the tank; this is to prevent the circulation of water in the pipe, which would cause an appreciable loss of heat; similarly the inlet pipe is always in contact only with the cold layer of water beneath the perforated diaphragm, and as heat is conducted through stagnant water only very slowly indeed, no loss of heat takes place through this pipe. The inventor claims that this device possesses great advantages compared with other methods of thermal storage.

The latest storage heater is one devised by W. R. Cooper, and made by Messrs. Purcell & Nobbs; it is illustrated in section in Fig. 5. The apparatus consists of an inner tank A, containing the heating element enclosed in a tube B, and an outer annular cylinder C, separated from the inner tank by an air space D. Cold water is introduced at E in the outer cylinder, the upper portion of which is in communication with the inner tank by stand pipes F F, which enter the bottom of the inner vessel. Hot water is drawn off from the top of the latter, and is replaced by warm water from the outer tank; baffles are provided as shown to prevent the incoming water from mingling with the hot water, so that the whole of the contents of the tank A can be drawn off without entraining any of the water which enters from C, until the level of the latter reaches the top of A. The purpose of the outer cylinder of water is to trap the heat radiated from the inner one, and being always at a much lower temperature than the water in

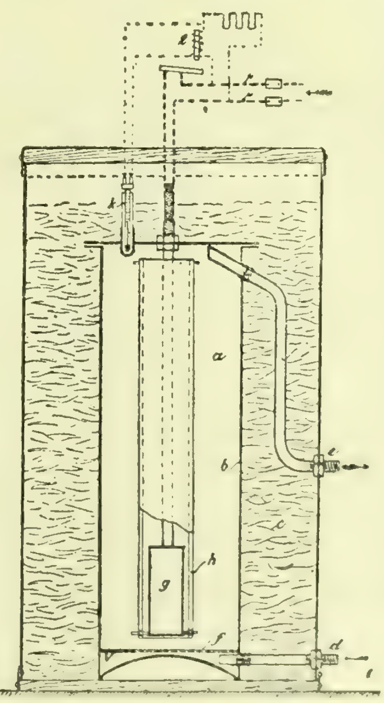


FIG. 3.—RITTERSHAUSEN APPARATUS.

a water space; b tank; c non-conducting layer; d inlet pipe; e outlet; f perforated diaphragm; g heating element; h circulating tube; [illegible]; k thermometer; l relay.

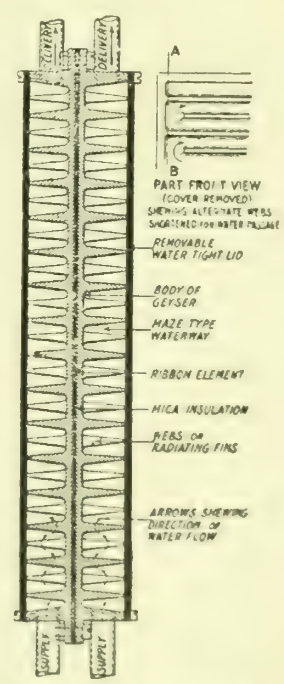


FIG. 4.—[illegible] GEYSER.

A, it need only be lagged with non-conducting material in the ordinary way. On starting the heater, the water in A soon becomes hot, so that it can be used without a long wait. If, however, the hot water is not drawn off, the surplus heat is transmitted across the air space to the outer jacket, more and

more rapidly as the temperature of the water in A rises, and thus the cylinder C serves as a reservoir for heat; it contains about twice as much water as the inner tank. The electrical input being suitably proportioned to the total volume of water, boiling is not likely to take place; but as a measure of precaution, a vent pipe is attached to the top of A, and is led upwards to a sufficient height to prevent overflow.

The foregoing heaters are all of the storage type; there are, however, cases in which an immediate supply of hot water is required, in unlimited quantity, at short notice. For this purpose instantaneous heaters are used, similar to the "geysers" heated by gas. Necessarily heaters of this kind make a heavy draught upon the supply mains. Nevertheless there are circumstances in which convenience is of greater importance than economy, and the fact that there is a market for such apparatus justifies a short account of their construction.

Fig. 2 shows a section of the Belenus electric boiler, made by Messrs. Eastman & Warne; it consists of a cast-iron block of cylindrical shape, corrugated on the inside in contact with the water, and deeply grooved on the outside. The heating elements, which consist of stout wire wound on refractory supports, are embedded in the slots, and are insulated from the iron by pure mica. Being practically surrounded by iron, the elements give up nearly all their heat to the latter, and they are securely protected from damp. A sheet-steel cover is placed round the boiler, the air space thus enclosed serving as a non-conducting jacket, and the cover can be further surrounded with sheet lagging if desired, to secure a higher efficiency, though this is not so necessary as in case of storage heaters, because the boiler is usually heated only for short periods. The heating element is divided into a number of

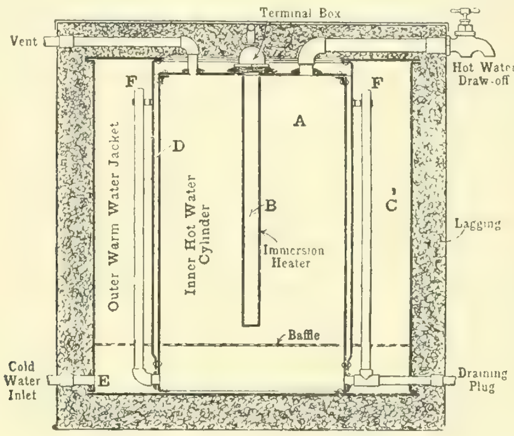


FIG. 5.—COOPER ELECTRIC WATER HEATER

separate circuits, so that the rate of heating can be regulated, the maximum power taken being from 3 kw. to 9 kw., according to the size of the boiler. It is, of course, obvious that this boiler can be used in conjunction with a circulating system and a hot-water tank, in which case the current can be kept on continuously at the rate of 250 or 500 watts.

Another device similar in principle to the Belenus boiler is made by Messrs. Belling & Co.; its construction is shown in Fig. 4. The body of the apparatus consists of two castings, flat on one side, and provided with fins or baffles on the other, as shown; when the flat cover is screwed on, the water is compelled by these fins to pass to and fro across the face of the casting, thus coming into intimate contact with the metal. The heating element is a sheet of resistance material, formed into a ribbon by suitable alternate slotting so that it has no joints or bends. This sheet is clamped between the two castings, from which it is insulated with mica. It will be seen that the whole of the heat evolved in the heating element must necessarily pass into the metal plates, except a very slight amount at the ends, an efficiency of 95 per cent. being claimed. A special feature of the Belling electric geyser is the control, which is applied simultaneously to the water and the electric current. The electric switch is mechanically interlocked with the water supply valve, so that the current cannot be turned on before the water, nor can it be left on when the water is turned off. This is effected by an ingenious double rack and pinion, with a free motion at each end of the stroke. The makers state that, starting with cold water, this geyser in 1 minute 40 seconds yields water at bath temperature—about 108° Fah. With an input of 10 kw., it gives 12 pints of hot water per minute, or 3 pints of boiling water per minute.

AERONAUTICAL ENGINES.

AT a recent meeting of the Institution of Automobile Engineers the subject of "Aeronautical Engines" was dealt with in a paper by Mr. A. Graham Clark. The problems involved in the design and construction of engines used for aeronautical purposes were, he observed, such as should make a direct appeal for solution to the automobile engineer, not alone on account of the commercial possibilities, but because the practical and scientific difficulties experienced were somewhat akin to those which had been overcome in the evolution of modern car engines, and because the production of a satisfactory engine would go far to eliminate one of the chief sources of danger. Unfortunately, with comparatively few exceptions, motor-car manufacturers had not given the subject the serious attention it deserved, but had, in some cases, endeavoured to obtain a high power-weight ratio by reducing the dimensions of the engine parts of their standard productions, and especially those of the cylinder and the crank case. It could not be too strongly emphasized that the conditions of service were not less arduous than those under which the ordinary car engine was employed, and therefore any sacrifice of strength or rigidity should not be considered for one moment.

The qualities which were either desirable or essential in an aeronautical engine were: (1) Reliability; (2) high power-weight ratio; (3) economy in fuel and oil; (4) low air resistance; (5) "controllability"; (6) freedom from vibration; (7) accessibility; (8) silence; and (9) cleanliness.

The need for the first requirement was obvious, as the failure of the engine might be attended with disastrous consequences. High power-weight ratio and economy in fuel and oil consumption were desirable on account of the increased radius of action possible with an engine possessing these qualities, while, in addition, the presence of excessive quantities of oil in the cylinder was a fruitful cause of irregular firing and consequent falling off of power. The importance of air resistance became more marked with increase in the speed, as the power absorbed in this direction varied as the cube of the velocity. Since many designers were raising the speed of their machines for the purpose of obtaining greater stability, the higher-powered engines which resulted would render it necessary that a greater amount of attention should be paid to the question in the future. It might be remarked in this connection that the horse-power required to propel a flat plate 3ft. diam. through the air was increased from about 6 to over 16 by increasing the relative velocity of the plate to the air from 50 to 70 miles an hour.

Although there was not the same need for "controllability" or flexibility as with engines employed on automobiles, it was, he said, none the less desirable, since at low speeds of rotation the propulsive or tractive effort of the propeller was insufficient to move the machine along the ground, and hence the pilot would be able to start up without assistance, if necessary. Further, as the engine was not required to develop its full power during horizontal flight and when alighting, the ability to vary the speed during descent was certainly preferable to the crude method of switching the ignition off and on. These remarks would apply principally to aeroplane requirements, but in dirigible work such a quality would be an advantage, because of the easy acceleration that could be given to the vessel without undue stressing of any part, as well as on account of the desirability of varying the speed while observations were being made.

The necessity for the elimination of vibration so far as possible would be obvious when the slender nature of the supports upon which the engine was carried was realised, especially as vibrations of an objectionable character might be set up in the various parts of the machine. The question of convenience of accesss was frequently overlooked, or disregarded. It must be realised, however, that from commercial considerations alone, apart from the addition to the time during which the machine could be used, it would be an advantage to be able readily to examine or dismantle any part. Silence was desirable, especially in machines intended for employment on military reconnaissance duties. Cleanliness was in the nature of a refinement, but it was none the less necessary.

Reliability might be regarded from two aspects (1) the

absence of structural weakness of any kind, and (2) an immunity from defective lubrication, cooling, carburation, and ignition. The first entailed a consideration of the question of weight, and in this connection it should be remembered that in any engine lightness must be achieved by construction, not by increasing the stress or by reducing bearing areas. There were many ways in which reduction in weight per horse-power might be made without the sacrifice of either strength or rigidity, the chief of which were as follows: (*a*) By the employment of materials of low specific gravity or great strength; (*b*) by limiting the volume of the material; (*c*) by reducing the number of parts subject to stress; (*d*) by the more economical use of the material; (*e*) by so disposing the material that it was better able to resist the loads which it was called upon to withstand; (*f*) by the use of the simplest construction possible; (*g*) by the adoption of air-cooling for the cylinders; (*h*) by running the engine at higher speeds and gearing the propeller down.

As regards (*a*), much had already been done in this direction; aluminium alloys were used for the crank case, alloy steels for cranks and cam shafts and connecting rods, and pressed steel for pistons, &c., until the further reduction of the dimensions of these parts would render them liable to excessive distortion. When proceeding as indicated in (*b*) the pistons might be reduced in weight by shortening the length of skirt; valves, by limiting the length of the stem; water jackets, by the use of sheet metal; the water carried, by having narrow water spaces; the bottom halves of crank cases, by employing sheet metal; entire crank cases, by allowing the minimum amount of clearance for the working parts; couplings, by removing metal where unnecessary; and flywheels, by the use of larger diameters, always provided that no detrimental effects were introduced thereby. If, however, the pistons were made very short they had a tendency to tilt, and limitations were thereby imposed. Valve stems must be long enough to allow of sufficient lift to give sufficient area for the ingress or exit of the gases and to afford an adequate length for the spring and guide. Water jackets of copper or other metal were permissible, provided that the methods of jointing to the cylinder at the ends, at the sparking plugs, and at the gas apertures were satisfactory, and that the jacket was free to expand independently of the cylinder.

One method in which (*c*) was effected was by the use of a single cam to operate two inlet valves, as in some Vee engines, or an inlet and an exhaust valve as in other engines, principally of the Vee and radial type, but yet in many designs long push or pull rods actuated the valves through rocking levers. This was, in his opinion, altogether inferior to an arrangement in which the valve was directly operated, for, apart from the greater weight entailed, the force required to actuate the gear was very great and necessitated the use of larger cam shafts and stronger springs. The more economic use of material (*d*) afforded an easy way of acquiring a light construction. By far the greater number of engines now manufactured were of the Vee, the radial, the semi-radial, or the rotary type. The length and weight of the crank case and shafts might thus be reduced considerably, but unfortunately other factors were thereby introduced which caused them to be less satisfactory than the vertical engine. The use of hollow shafts and rods, H-section connecting rods, &c., and the care taken to subject parts to tensile rather than compressive stress, were illustrative of the methods referred to under (*e*), and these might be widely adopted with advantage wherever practicable. Great care, however, must be exercised in determining the proportions of the parts so constructed, in order to ensure that there should be no risk of collapse.

The relative merits and demerits of air-cooling was next discussed. Undoubtedly, he said, the weight could be much reduced by this method, and the absence of water joints and connections tended towards simplicity, but it was well known that, in general, a lower brake mean effective pressure was obtained with this type of engine than with that using water-cooling, largely because of the greater frictional losses between the piston and the cylinder and the reduced charge of gas taken. The former were due to the distortion of the cylinder owing to the unequal expansion which resulted from lack of uniformity of cooling, as well as the higher temperatures at which these engines were run, while the reduction in the charge taken was attributable to the high temperatures within the cylinder. Further, the additional details which became necessary to ensure sufficient air passing over the cylinders should receive attention. If a separate fan were employed, and the cylinders were closed in by a sheet-metal casing, the design required very careful development to ensure that the ultimate results achieved were even equal to those obtainable with water-cooled engines—in fact, in most cases the weight per horse-power was greater for the same speed of revolution of the crank shaft.

The whole matter was obscured by reason of the fact that many of the most successful flights had been made with air-cooled engines of the rotary type; indeed, it could not be denied that but for the advent of such engines aviation would never have progressed so far as it has, because water-cooled engines at that time derived much of their lightness from a reduction of the factor of safety employed and an increase in bearing pressures, with the result that trustworthiness was impaired. Any engine, therefore, that could give equal results with a reduction in weight was welcomed. The author was of opinion, however, that the large amount of power absorbed in rotating the cylinders, the increased air resistance offered, the irregular distribution of heat in the cylinder walls, and the variation in cooling effected at varying speeds rendered the adoption of this method of reducing weight a very doubtful expedient for obtaining a high effective horse-power per unit of weight now that trustworthiness had assumed such an important aspect.

With regard to the method indicated in (*h*), it must not be forgotten that the increase of power obtained by raising the speed of revolution was not an entire gain, for the weight of the gearing and its supports, possibly some reduction in the mean effective pressure, and certainly the loss of power through transmission by gearing would cause the ratio of weight to power to be somewhat greater than was indicated by the increase in the speed. Also, higher speeds of revolution naturally tended to increase the wear of the moving parts and so render the possibility of engine failure greater, since few engines were able to run for prolonged periods under such conditions. Hence such a system was not recommended for general adoption.

ACTION OF CARBONISING MATERIALS.

In a paper on the "Action of Various Commercial Carbonising Materials," presented at the Cleveland meeting of the American Institute of Mining Engineers, Mr. R. R. Abbott said that formerly case-hardened steel was held in more or less contempt, since it was considered a cheap substitute for tool steel. This was no longer the case. The development of the motor-car industry, and coincidentally that of modern alloy steels, had resulted in overcoming many difficulties formerly experienced in case-hardening. This result had been accomplished by increased knowledge regarding the analysis of the steel which would respond most readily to case-hardening, and by more careful methods of treatment of the carbonised steel.

The ordinary method of carbonising consisted in packing the steel with the carbonising material in cast-iron boxes and placing them in a furnace at a temperature of from 1,500° to 1,900° Fah., for a time sufficient to give the required depth of case. The steel was then either quenched directly from the box, or was allowed to cool without unpacking, and finally was given a single hardening heat, or, for special work, two or three heats. The carbonising material mostly used consisted of granulated bone. Within the last four years many manufactured compounds had been placed on the market, consisting largely of some form of carbon or carbonaceous material, with or without the addition of chemicals. Steel would absorb carbon placed in contact with it at the temperature of the atmosphere. The reaction was exceedingly slow, but increased rapidly with increasing temperature. Below 1,500° Fah. the absorption was too slow to be commercially important. Various causes combined to make it impracticable to carbonise above 1,900° Fah. In general, carbonising was carried out at temperatures ranging from 1,550° to 1,750°, and higher temperatures were used only when the quality was not as important as the cost. Broadly speaking, the higher temperatures could be employed for high-grade work when proper facilities were at hand for a

careful regulation of the temperature, and a knowledge was possessed of the correct subsequent heat treatment of the carbonised product.

When steel was carbonised, the carbon did not penetrate in a gradually decreasing content from a high carbon exterior to the uncarbonised core, but rather in a series of steps. Many of the commercial materials behaved differently in carbonising, and even under exactly the same conditions of time and temperature, different depths of penetration or different per cents. of carbon, or both, were obtained. In order to produce good results in case-hardening, a uniform material must be used, and the treatment of steel subsequent to carbonising must be suited to the nature of the case produced.

An investigation was undertaken to compare most of the important commercial carbonisers as to cost of carbonising, rapidity of carbonising, and the nature of the resultant carbon zones. In discussing the results, Mr. Abbott stated that the use to which case-hardened steel was to be put should be the deciding factor in selecting the material with which it was to be carbonised, and also to a less extent the temperature of carbonisation should be determined from similar considerations. The question of carbonising material was one which usually was not given the attention which its importance demanded. A few sample tests conducted under intelligent direction would often result not only in a great saving of money, but in increased efficiency with regard to the product.

INSTRUMENTS FOR TEMPERATURE MEASUREMENT.

AMONGST the numerous instruments shown at the recent Physical Society's Exhibition, the pyrometers of Mr. Robert W. Paul, New Southgate, London, were of striking interest to engineers. One form of pyrometer shown consisted of an iron-eureka thermo-couple mounted in a bent brass tube, fitted with a nipple and gland for screwing into steam pipes, superheaters, &c. Pyrometers of this construction are employed very successfully in measuring the temperatures of locomotive superheaters, the indicating instrument being of the well-known Paul unipivot type. Base-metal thermo-couples were also shown, suitable for boiler flues, &c., of extremely robust form to withstand severe workshop conditions.

Thermo-couples of platinum-rhodium elements, mounted in tubes of quartz and steel were also exhibited, for measuring higher ranges of temperature. The merits of the unipivot indicators for these thermo-couples are now so well known that it is unnecessary to describe their construction here in detail. The mounting of the moving coil on one pivot at the centre of gravity of the moving system presents a very sensitive movement, which is at the same time extremely robust and capable of withstanding hard usage. This fact has been amply proved in their long and successful use in measuring the temperatures of locomotive superheaters.

A new feature was introduced by Mr. Paul at the Exhibition, in connection with the above thermo-couples, namely, the adoption of an electrical device for compensating for changes in the "cold-junction" temperature, and also for producing a false "zero" on the indicator, thereby enabling a much more open scale to be secured.

Other new instruments in temperature measurement consisted of thermo-static relays for the control of temperatures up to 300° C. (570° Fah.). Two types were exhibited, the one to give readings up to 550° Fah. (290° C.), and with an electrical contact which could be adjusted to ring an alarm, or work a solenoid control, &c., at any required temperature. Such an instrument is found extremely suitable for japanning ovens, electrical cooking stoves, &c. The second instrument was fitted with both maximum and minimum contacts.

Resistance and radiation pyrometers were also on view, and each form has its own special points of merit. One main feature, however, which struck the engineer in all the types exhibited, was the strong mechanical construction, combined with accuracy and sensitivity of working.

Electric Safety Lamps in Mines.—Mr. R. A. S. Redmayne, Chief Inspector of Mines, in a recent report, alludes to the subject of electric safety lamps for mines, and states that the number in use had increased from 2,055 in 1910 to 4,298 last year.

NOVEL TYPE OF BLASTFURNACE CONSTRUCTION.*

BY J. E. JOHNSON, JUN.

THE general construction of blastfurnaces has undergone no radical change in more than a generation. When the old style of masonry construction was replaced by the steel shell, the masonry piers were simultaneously replaced by columns never less than 6, and frequently 12 or 16 in number, set under the mantel ring. The furnace itself has recently been the subject of radical changes; in some cases the thin-lined construction has been adopted for the whole furnace, and in other cases it has been adopted for a zone immediately above the bosh, raising the mantel several feet to make this possible, but still the style of construction with columns set immediately under the mantel has been universally followed.

In spite of the apparent permanence of this type of construction, it is open to grave disadvantages from the operating point of view, which may be briefly outlined as follows: The bustle pipe is necessarily outside the columns, as the slope of the bosh and size of the crucible are such as to leave but little room inside the columns for the necessary water piping, &c.; consequently, the penstocks have to pass between the columns. Moreover, the hearth jacket requires a diameter but little smaller than the circle of the inside of the columns, and as a result the cooling-water ditch for protection against breakouts is exceedingly limited in width.

Still another result of this construction is less immediately disastrous, but leads eventually to a very serious condition. The space between the base of the columns and the hearth jacket being so small, the whole structure is necessarily set on one foundation and the continual expansion, which all masonry structures undergo from continued heating, gradually pushes the column bases out.

It has seemed to me that it would be possible to avoid these evils by building a framework of structural material strong enough to carry the weight of the whole furnace and to support this on columns set at the corners of this framework, which would throw them so far back from the furnace proper that they would be safe from all danger from breakouts or other accidents, and at the same time would allow room enough around the furnace for necessary access to all parts with great safety, ease, and speed in all necessary work.

When re-designing our furnace, we first laid it out with the idea of using a triangular frame of girders with a column at each angle, and in order to get the girders above the bustle pipe we considered using the thin-lined construction for several feet above the bosh angle and letting the mantel at the top of this thin zone rest directly on the girders. On further consideration, however, there were two features of this design which we did not like. We desired to use the steel bosh jacket construction, cooled by external sprays, which has proven so durable and satisfactory at many plants, and which avoids entirely the stepped bosh wall, almost as angular and rough as a flight of steps, into which the cooling plate construction soon wears.

In regard to the three-column construction, while it sets the columns back further from the furnace than they come with the four-column type, in the event of a serious accident around the bottom of the furnace, it was conceivable that one column might be sufficiently affected by heat to yield, and with the three-column construction this would throw the whole furnace to the ground. With the four-column construction on the other hand, if anchor bolts to hold the structure down to the foundation were used, one column could fail completely and the two adjacent to it would carry the structure with the assistance of the counterweighting action of the column opposite to the one that failed. This, of course, would only be true if the columns were made so strong that any two would carry the structure.

Accordingly, the four-column construction was adopted and the columns were designed to have an ample factor of safety with any two of them supporting the entire weight of the furnace. To raise the girders above the bustle pipe and at the same time to avoid the high mantel possible only with the thin-lined zone above the top of the bosh, it was necessary to support the shell on the girders by brackets. To reduce the

* Abstract of paper presented at the Cleveland meeting of the American Institute of Mining Engineers

local stresses on the bottom of the shell, due to these brackets, eight of them were used.

It is obvious that the mantel plate would be entirely unsupported except at its outer edge and that it might deflect at the inner edge, owing to the weight of the brickwork, if some provision were not made to prevent this. The extent to which this action could occur in view of the brick being so firmly supported at the outside by the heavy angle riveted to the shell, is problematical, but it was not desired to take any chances and a cantilever bracket was therefore designed to support the mantel plate from below to within a short distance of its inner edge. The angles which rivet the bracket to the shell continue down below the mantel and support a heavy, vertical plate, the inner end of which projects under the mantel plate, while the outer end is prevented from rising under the weight so applied by heavy angles fastened to it, which pass up outside the girder and take hold of the outer end of the shell bracket. In order to prevent any possibility of deflection of the mantel plate between these brackets, heavy channels were riveted to the inner ends of the cantilevers in such a position that the centre of the channel comes as close as desirable to the edge of the mantel plate.

Four independent piers of concrete were provided, as shown in the accompanying illustration, and these were set back at a great distance from the foundation of the hearth of the furnace proper. These piers are at such a distance from the foundation of the hearth and so entirely separated therefrom that it seems impossible there should ever be any transmission of the expansion of the hearth through the soft dirt between the two, which could force the piers out of position.

Brackets were introduced between the top of the column and the bottom of the girder on each corner to prevent any possibility of the columns failing by leaning all in the same direction circumferentially. Across the corners of the main girders, channels were riveted at top and bottom to form diagonal braces. These were latticed together vertically for greater strength. The girders were so located that the inner edges of their flanges were 4in. from the shell at the closest point, and the corner braces were put 7in. from the shell at the closest point, thus leaving plenty of access to the shell for anything that may be necessary, even behind the girders. The brackets are not riveted to the girders either at top or bottom.

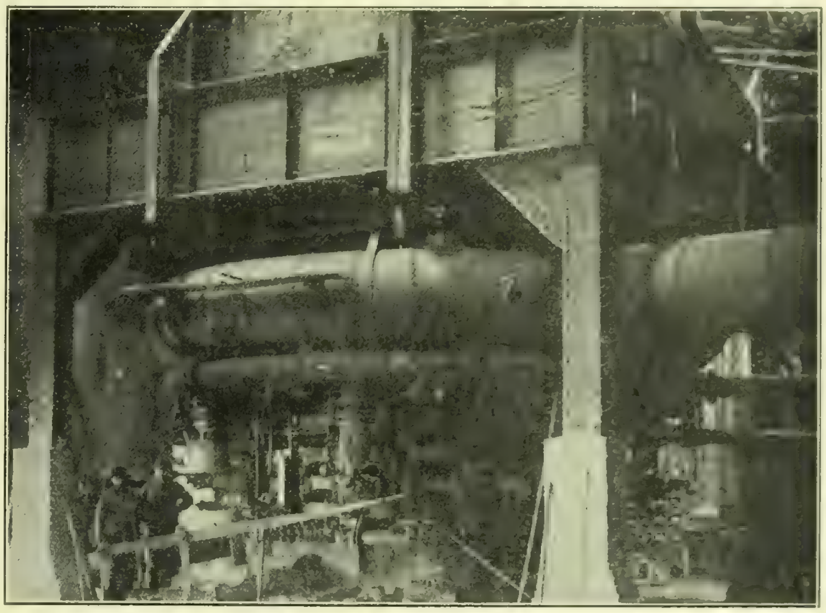
The inward thrust at the top of the bracket comes on the seam uniting the bottom and second shell plates and throws this into compression. The proportions of the bracket are such that the inward reaction from each one is relatively slight and the probabilities are that the sheets alone would be able to resist it without deformation, but in order to leave no doubt whatever on this score, a heavy, 6in. angle was run entirely around inside the shell just at the bottom edge of the second sheet in such a position as to receive the full thrust from the brackets.

In regard to the strength of the girders, they were designed to be safe with a low unit stress, assuming that the weight of the shell, top rigging and top house lining, back lining, bustle pipe, and the entire charge from the hearth to the stock line, were supported on them. This last condition is most unlikely, but it is conceivable that the furnace might become so badly scaffolded just above the tuyeres that the weight of the whole charge would come on to the mantel and so on to the structural work. We, therefore, provided against this contingency in the design.

The general appearance of the furnace in operation is shown in the illustration. Two men stood shoulder to shoulder as nearly in line as they could be placed between the wicket on the penstock and the nearest column, in order to show the amount of room available. In addition, the tuyere is not in line radially with this column so that the access to the tuyeres is even more unrestricted than would be indicated by a photograph. This could have been made even better than it is, except that the hot blast main was so located as to prevent placing the columns four-square with the line of the tapping hole. The columns are bricked up to a height of 6ft. to prevent any possibility of damage to them by fire. We considered also making provision to keep them filled with waste water for several feet, but this was found not to be necessary. The brickwork surrounding them consists of hard firebrick laid in cement and is almost indestructible.

The accessibility of the furnace for work of any kind is remarkable and I do not think that anyone who had worked around a furnace of this design would ever desire to return to the old type of construction. We had some trouble with the cinder cooler on one occasion, since the furnace was blown in and got quite a little iron into the ditch beneath it. It ran around the furnace a distance of 7ft. or 8ft. This would have been sufficient to tie itself behind one or more columns with the old construction and would have been very difficult to get out. As it was, we simply tore down the 4½in. wall from the outside of the ditch, pulled the chunk away from the hearth jacket, out of the ditch, in one piece and replaced the 4½in wall. This accessibility is also a great advantage in working at water pipes, and especially in following these from the cocks on, the circle pipe to the cooling member that they supply. The very short and direct connection from the bustle pipe to the tuyeres also is shown. Objection will probably be made to this construction on the ground of cost, but the great saving in real cost over the standard construction is one of the features which pleased us most.

When the steel bosh jacket is used with the ordinary type of furnace, it has necessarily to be fitted up and riveted



METHOD OF SUPPORTING ENTIRE WEIGHT OF BLASTFURNACE

together in several sections inside the columns, and, in fact, it is commonly attached to the edge of the mantel ring, as it is put together with the necessity of a great deal of fitting of the vertical seams. In the present instance the bosh jacket was built entirely independent of the furnace and when the construction had advanced far enough to receive it, it was simply shoved in through the columns, hoisted into position and riveted, the entire job taking only about two days as against two weeks that would have been required had it been built up in place in the customary way. We consider that we made easily a saving of five weeks by this type of construction.

It is customary to regard charcoal furnaces as insignificant in size, but this furnace is 60ft. high and of a size that would make from 200 to 300 tons per day with moderate driving on coke iron. Furnaces have such an enormous capacity for exerting destructive energy that the tendency in the minds familiar with them is to over-estimate their actual weight. It is doubtful if the weight of a large coke furnace figured on the basis described would exceed 2,000 tons, and there is no difficulty whatever in carrying a load of this amount with a construction of this kind.

It may be well to point out that the construction lends itself particularly well to the thin-lined type of furnace, because the weight of the lining in such a furnace is an insignificant fraction of that of a standard, thick lining, and because some outside structure is generally necessary for supporting the platforms, spray apparatus, &c., even if not the furnace top proper. This can all be done with great advantage from the girder frame if the type of construction

here described be used. It is well to point out also that if the cooling plate construction of the hearth is used so as to form an adequate support for a thin lining in the zone immediately above the bosh, then the high mantel, which results from that construction, may be directly supported on the girders.

A furnace designed on the plan described is not only feasible, but a safe and substantial construction. This construction is especially well adapted to the thin-lined, or partly thin-lined furnace. Its convenience in operation is so much greater than that of the older type of furnace that there is no comparison from an operating point of view. The time to be saved by the use of this construction, at least in rebuilding, is so great as to constitute a money-saving of far greater extent than the slight excess cost of this construction over the standard.

THE USE OF ELECTRIC POWER IN STEEL MILLS.*

BY STEWART C. COEY.

THE increase in the use of electric power in steel mills has more than held its own with the rapid advance of the application of electric power in other lines of industrial work. Electricity was first used in steel mill work for lighting purposes in 1881, in which year the first Brush series arc light dynamo was installed at the Brown, Bonnell, & Co.'s plant in Youngstown, Ohio. About 10 years later the Edgar-Thomson Company, in Bessemer, Pa., installed a 50 h.p., 250-volt direct-current generator, and this machine, which was a large one for its time, was used to furnish power to an experimental crane over the soaking pits in the blooming mill.

From 1892 to 1902 the development of the electric motor drive was carried on by the use of the 220-volt direct-current system. It was quite generally recognised that, due to the fact that steel mills are of necessity spread out over large areas of ground, a great saving could be accomplished by the distribution of power by means of electricity for driving all auxiliary apparatus. However, during this period there was a constant check on electrical development, as there were neither motors nor control apparatus constructed to meet steel mill conditions. At the end of the period a power plant of 500 kw. capacity was considered large for a steel mill.

Within the last 10 years a number of the points that retarded the development of the use of electricity in steel mills have been removed by the general advance of the art and by the development of special apparatus to meet steel mill conditions. The development of the alternating-current system of generating and distributing electricity, the mill type motor, the steam turbine, and the gas engine have all been big factors in the rapid advance of the use of electricity in steel mills in this period.

The use of 220 volts, direct current, necessitated the use of generating units that were large in size and high in cost per unit of power capacity. These generators were driven by reciprocating engines which gave economical conditions of operation over only a small range of load. The economy of reciprocating engines also has to be watched closely to keep it up to its maximum efficiency of operation. In distributing the electric power at 220 volts it was found that about 1,500ft. was as far as power could be economically distributed at this voltage.

The development of the alternating-current system of power generation and distribution made it possible to centralise the generation of power and not only give the added advantage of centralisation, but also to make use of the blastfurnace gases for generating power for use in all parts of a group of steel-making and finishing mills.

When alternating current was first used in steel mills, a voltage of 2,200 was adopted in a number of the plants. Later developments resulted in the adoption of 6,600 volts, 3-phase, and 25 cycles as the standard voltage for steel mill work. This is a voltage at which power can be economically transmitted at distances up to about 6 miles, and it is also a good generator voltage. While it is possible to generate electricity at higher voltage than this, it is not practical to consider higher voltages in steel mill work, as the large amount of dirt and gas in the air makes conditions harder than for ordinary operation. The 3-phase system has become standard on account of its good electrical properties in motor operation, and a frequency of 25 cycles has been almost universally adopted in steel mills, as comparatively low speeds are desirable in a large percentage of the motor applications.

The type of prime mover for electric power generations that is best suited for use in steel mills is a very broad subject, and in the majority of cases it is a problem that has to be gone over very carefully for each individual plant. Wherever possible the sources of energy which have in times past been allowed to go to waste are now utilised and turned into electrical energy. The blastfurnace gases, which are not used in the stoves, are now either used under boilers to generate steam, which is in turn used to operate blowing engines and steam turbines, or else the gas is used directly in gas engines as a means of generating power. The problem as to which of the two methods of using the blastfurnace gas should be adopted is very complicated, and one that takes in a number of different factors.

On a theoretical basis the amount of gas necessary to generate electricity with a turbine plant, the gas being burned under boilers, is nearly twice as much per kilowatt-hour as in the case of a gas engine installation. Commercial tests indicate that this figure averages on existing installations about 20,000 B.Th.U. per kilowatt-hour for the gas engines and about 30,000 B.Th.U. per kilowatt-hour for the turbine installation with gas burned under the boilers. This is a very important item, effecting, as it does, a conservation of energy. However, there are other items to be taken into consideration that are very greatly in favour of the use of turbine plants.

In considering the final cost of power, the saving in one item may very easily be offset by the increase in another item. It is the item of fixed charges that runs the cost of power up in gas engine plants. The initial cost of a gas engine installation per kilowatt of generating capacity installed will vary with the conditions, but a value of $125 per kilowatt is very close to the average condition. In the case of a turbine installation with gas-fed boilers this figure will average about $75 per kilowatt.

The depreciation of gas engines is very much higher than in the case of turbine units, due in a large degree to the fact that in the gas engine there is a rapid variation in the stresses on the engine during each cycle of operation, while in the steam turbine there is a constant torque applied. A value of 8 per cent. for the gas engine plant, which corresponds to a life of approximately 10 years, and 5 per cent. for the turbine plant, which corresponds to a life of approximately 14 years, is, if anything, in favour of the gas engine plant.

The interest on the initial investment can be taken at 6 per cent. in each case. If, as is often the case, the company considering the installation has only a limited capital or borrowing capacity and could use the money represented in extending portions of its producing plant which would net larger returns on the money than 6 per cent., the percentage returns which this extension would bring should be used in place of the actual interest in this special case.

Experience has shown that the maintenance and repair charge is more than double in gas engine plants, for the same reasons that the depreciation charges are higher. The operating labour is also higher in gas engine plants than in turbine plants.

If we neglect these two items and use simply the interest and depreciation figures, with 1 per cent. for taxes and insurance in each case, we have a total fixed charge of 12 per cent. on the turbine plant and 15 per cent. on the gas engine plant.

The effect that this fixed charge has upon the cost of power depends entirely upon the load factor. If the load factor of the Youngstown Sheet and Tube Company is taken as in a measure indicative of the average in steel mills, we get a figure considerably lower than most comparisons are made on. The total present capacity in this plant is 9,000 kw., and during the last year there has been generated 36,000,000 kw.-hours, or an average of 4,110 kw. for each hour in the year. This is a load factor of 46 per cent., and incidentally it is well to note that this plant is operating with as small an equipment of spare apparatus as it is policy to

* Paper read at the Pittsburg meeting of the American Iron and Steel Institute.

operate with in a steel mill. This load factor would mean that the fixed charges would be as given in the table.

Comparing Fixed Charges of Gas Engine and Turbine Installations for the Same Output.

	Fixed Charges per cent.	—Per kilowatt of capacity— Plant Cost.	Fixed Charges	Power Generated per year. kw.	Fixed Charges per kw. hr.
Gas engine installation	15	$125	$18.75	4030	0.46c.
Turbine installation ...	12	75	9.00	4030	0.22c.

In other words, the fixed charges under these conditions are 0·24 cent more for the gas engine installation than for the turbine installation.

Commercial tests on turbines show actual operating efficiencies of less than 20lbs. of steam per kilowatt-hour. Power for operating condenser auxiliaries adds about 10 per cent. to this, making the operating efficiency 22lbs. per kilowatt-hour of power delivered. The cost of steam generated from coal determined from the average at the Youngstown Sheet and Tube Company is 10 cents per 1,000lbs., including boiler-house auxiliaries and labour. This would give a value of 0·22 cents per kilowatt-hour as the value of the steam generated from coal for a turbine installation.

From the foregoing it can readily be seen why in this special case it is impractical to consider the use of gas engines. If the value of the gas is neglected, a turbine installation using coal as a fuel at the prices prevailing in this district would generate power under these conditions at a cost per kilowatt-hour less than could be obtained by the use of gas engines. Where the price of coal is high the cost per kilowatt-hour changes, and this cost comparison changes in a corresponding degree.

Leaving aside all cost considerations, the main arguments in favour of the steam turbine are the reliability of its operation and its good operating efficiencies over wide ranges in load. Reliability of operation is a factor that means more in steel-mill operation than in any other line of industrial work, as a shut-down in the power plant of a few minutes is liable to mean a big tonnage loss in one or more of the various departments.

A source of power which has been developed in late years is found in the use of exhaust steam from large non-condensing reversing engines which are quite common in a number of steel mills throughout the country. This steam is collected in regenerating tanks and used to produce power by means of low-pressure turbines.

At the Youngstown Sheet and Tube Company there is a 1,500 kw. mixed-pressure turbine operating on the exhaust from the blooming mill reversing engine. This installation furnished during the last year 5,000,000 kw.-hours of energy to the switchboard, from what was before waste energy. After deducting the amount of power represented by the extra amount of steam used by this turbine in generating the 2,000,000 kw.-hours which it generated in this time on high-pressure steam over what would have been used by a turbine designed especially for high-pressure steam and the energy equivalent of the added back pressure on the reversing engine, there is left approximately 2,500,000 kw.-hours, which represents the actual amount saved by the installation. One point in favour of this type of an installation is that it requires no extra boiler capacity and tends to keep the load on the boiler-house more uniform, as the machine is only taking high-pressure steam when the mill engine is down. The ease with which alternating-current stations can be run in parallel makes it possible to utilise these so-called waste energy sources and still operate the various sources of power in electrical connection.

In considering the problem of electric power generation and distribution, the connecting link or switchboard is likely to be neglected. The proper design of the switchboard very often determines the success or failure of a power installation. It is only due to the development of the oil switch that it is possible to handle large alternating currents at high voltages with safety.

As has been said before, the standard generator voltage of 6,600 volts is economical for transmission purposes up to about 6 miles. Where it is desired to transmit to greater distances than this it is the practice to use step-up transformers to give a line voltage of 22,000 volts for transmission purposes, with step-down transformers at the other end of the line to give 6,600 volts, or whatever voltage is desired for distribution.

After getting the electricity to the point at which it is desired to use it, the problem of the proper method of distribution in the mills presents itself. On account of the insulation problems in the mills proper, it has become customary to use 220 volts, either alternating current or direct current, for all mill motors except the very largest ones. Large roll motors and pump motors are built for 6,600 volts, but it is not generally considered good practice to use 6,600 volts direct on motors of less than 500 h.p. For use on all constant-speed work, the alternating current motor is desirable, and for this type of work it is customary to use induction or synchronous motors depending on the special conditions of service.

Whether alternating or direct current should be used on the roll tables, cranes, and other steel mill auxiliaries is a problem that has been discussed very seriously among steel mill electrical engineers, and opinions are greatly divided as to which type of motors it is advisable to use. If 220-volt alternating motors are used it is necessary only to use alternating-current transformers to step down the voltage from 6,600 to 240 volts, but these transformers have to be large in kilovolt-ampere capacity, as these auxiliary motors run for a great portion of the time underloaded, giving a poor power factor for the combined load. If 220-volt direct-current motors are used, it is necessary to use motor generator sets to transform the alternating current into direct current, with a loss of power at this point of about 12 per cent. more than in the alternating-current transformers, which have an efficiency of about 98 per cent.

The initial cost of the two systems is about the same, being if anything slightly in favour of the direct-current system. For instance, on a certain contemplated system, the average cost of alternating-current motors and control equipment was found to be $25 per horse-power, while the direct-current motors and control equipment averaged $21 per horse-power, showing a difference of $4 per horse-power in favour of the direct-current equipment. On this auxiliary apparatus there is always a portion of it that is working under light load or not operating at all. As an example, in a blooming mill, certain tables will operate at various points throughout the mill as the steel goes through, but never all at one time.

On cranes it seldom happens that all the various motions are called into action at one time. As a matter of fact, it is found that this auxiliary apparatus gives a load in kilowatts that is approximately one-quarter of the total rated horse-power of the motors. Motor generator sets cost about $14 per kilowatt of capacity more than transformers, which figure would be offset by $16 additional cost of the alternating-current motors and control over the cost of the direct-current motors and control, as it is only necessary to have 1 kw. of motor generator set capacity for each 4 h.p. of auxiliary motors installed. The main point where the alternating-current motor saves is in the elimination of the commutator, but this is offset to a certain extent by the fact that the air gaps in alternating-current motors must of necessity be less than in direct-current motors. An actual comparison of the air gaps in a comparative line of alternating-current and direct-current mill motors shows that the direct current motor has twice the air gap that the alternating-current motor has on an average.

This results in a big increase in bearing trouble, which offsets to a large extent the saving obtained by the elimination of the commutator. However, the point on which the whole question hinges is, in the writer's opinion, the fact that the control of the direct-current motors has been developed better and is simpler than for the alternating-current motors. By the developments of the last year it is possible to use automatic control on all the direct-current auxiliary motors at about the same cost as manual controllers and get a control that is both simple and effective. The saving gained by the use of automatic control, by reducing the number of breakdowns both electrical and mechanical, was the determining fact in causing the Youngstown Sheet and Tube Company to continue the use of 220-volt direct-current motors for auxiliary motors in the new developments. These same

reasons apply on crane motors, with the additional fact that the use of dynamic braking cannot be obtained in a satisfactory manner if alternating-current motors are used on crane hoists. By the use of dynamic braking hoist controllers and the elimination of the mechanical brake at least one-half of the troubles with cranes are at once done away with.

The use of direct-current auxiliary motors also allows for the correction of the total power factor of the plant. This is accomplished by designing the motor generator sets to operate with a leading current in the synchronous motors. This reduces the losses in the transmission line and turbo-generators, and compensates to a large extent for the increased losses in the motor generator sets as compared to the losses in alternating-current transformers.

It is quite possible that a simplified system of control may be developed in the near future for alternating-current motors that will offset this advantage in favour of the use of direct-current motors for reversing and crane service. The rapid developments of the last 10 years indicates that this is only one of the minor possibilities of the developments that undoubtedly will come in the use of electricity in steel mills.

WILLANS & ROBINSON'S VALVE GEAR FOR INTERNAL-COMBUSTION ENGINES.

THE accompanying illustrations show two arrangements of valve gear for internal-combustion engines, the invention of Messrs. Willans & Robinson, Ltd., Victoria Works, Rugby. The arrangement shown in Figs. 1, 2, and 3 is adapted for engines working on the 2-stroke cycle and for driving in one direction only. In Fig. 1 A is an eccentric keyed on to the crank shaft. The eccentric strap B imparts an up and down and also an oscillating motion to the rod C. This rod extends through a block D pivoted to a slide block E and at its upper end carries a roller F. Above the roller F is a lever G having a cam projection on its underside for the roller to act upon. H is a lever by which the slide block E can be moved sidewise

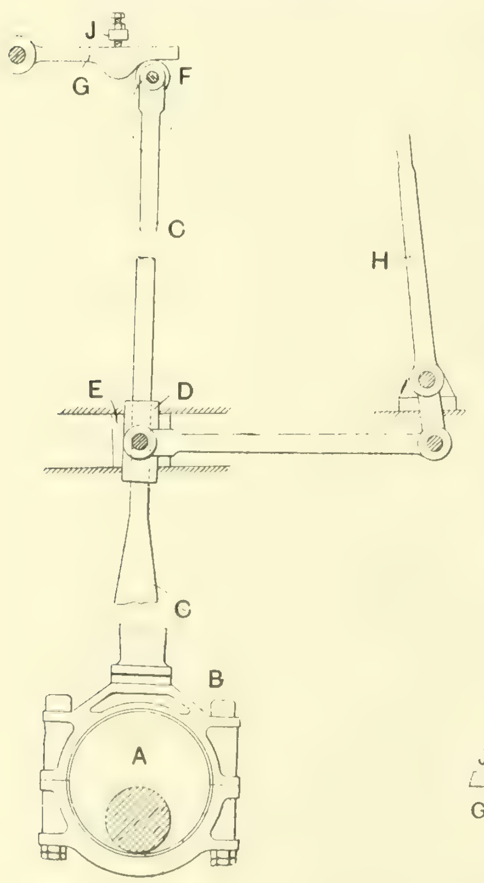


FIG. 1.

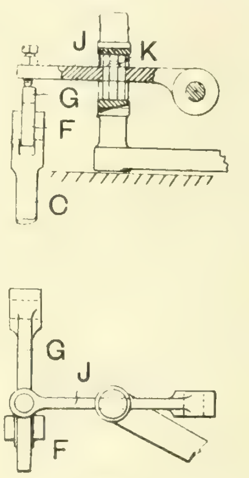


FIG. 2.

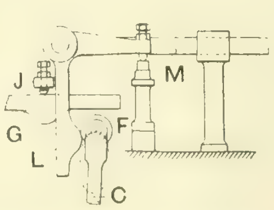


FIG. 3.

WILLANS & ROBINSON'S VALVE GEAR FOR INTERNAL-COMBUSTION ENGINES.

in a direction parallel with the lever G. In Fig. 1 it is shown to be thus moved sidewise into a position in which the roller F as it rises upwards is not brought against the cam surface. For normal working the block E would be moved to the left by the lever to bring the roller F into a position in which as it rises it strikes against the cam surface and gives an upward movement to the lever. The cam surface is arranged to give a required lift to the valve for which it is designed. In the illustration it is shown adapted to a fuel valve of the "Diesel" type. By moving the block E more or less to the left a

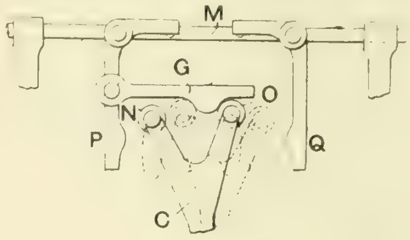


FIG. 4.

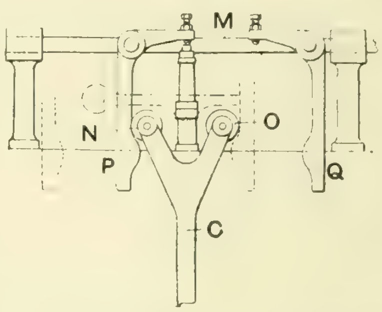


FIG. 5

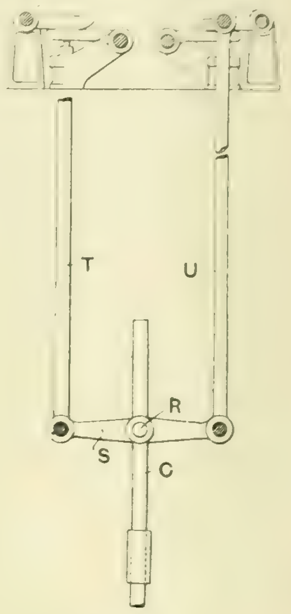


FIG. 6

WILLANS & ROBINSON'S VALVE GEAR FOR INTERNAL-COMBUSTION ENGINES.

greater or less lift may be obtained to suit the conditions of running. J is a second lever at right angles to the lever G and resting at its end on the top of this lever as shown in Fig. 2, so that the upward movement of the lever G imparts an upward movement to the lever J, which in turn is arranged to lift a fuel valve and needle J of a Diesel engine. When by a further movement of the lever H the roller F is moved still further to the right past the position in which it is shown in Fig. 1, a vertically hanging cam lever L is, by interposed mechanism, then brought into position for its cam surface to be acted upon by the roller F, whilst the other arm of the lever is brought into a position by which it can actuate a starting valve as shown in Fig. 3. In Fig. 3 the axis of the bell crank lever is shown to be carried by a rod M to which an endwise sliding movement can be given to carry the bell crank lever into or out of acting position.

Figs. 4 and 5 show a modification adapted for 2-stroke cycle reversing engines. In this case a double-ended eccentric rod C is used carrying two rollers N and O. Two starting cam levers P and Q are also carried by the sliding rod M, as shown in Fig. 5. For running in either direction the roller O or N acts upon the cam surface of the fuel cam lever G, the starting cam levers then being in a mid position clear of both rollers as in Fig. 4. On pulling the roller O out of gear and into mid position as in Fig. 5, the rod M is drawn along to bring cam lever P into position to act upon the starting valve and to be itself acted upon by the roller N, as shown in Fig. 5, thus giving starting position for one direction of running. A further movement of the starting lever H causes the rod M to be moved in the opposite direction to bring cam lever Q into position to act on the starting valve and to be itself acted on by the roller O, so giving starting position for the opposite direction of running and finally the rod M is brought back to the central position and the roller N is brought into position to act on the fuel cam lever G for continuous running in this direction. Fig. 6 shows how scavenge air valves are worked from a point R on the eccentric rod C. If two sets of valves are used, as shown, the motion may be transmitted by a freely swinging bar S through rods T and U to suitable levers above the valves. The lift of one set of valves will be the same as that of the other for any position of R, if they are provided with equally strong closing springs, since the bar S is free to set in any position with regard to the eccentric rod C.

For a 4-stroke cycle engine the eccentric may be driven from a half-time shaft or the gear may be moved away by sliding the pivoted block D by a suitable half-time gear every other revolution.

INDUSTRIAL AND TRADE NOTES.

Australian Steel Contract.—The contract for the whole of the structural steel work for the engineering workshops of the Victorian State's new shipbuilding establishment at Williamstown has recently been awarded to Messrs. Dorman, Long, & Co., Ltd., of Middlesbrough, in face of severe competition not only from the United States, but from Continental Europe.

Motor-cars in Australia.—The automobile and vehicle industry generally is, according to the American Consul at Sydney, being vigorously carried on in New South Wales at the present time Cars are being registered at the rate of almost 50 per week, and the latest returns of the traffic department show that there are 5,225 registrations of automobiles and 3,600 motor cycles. The chauffeurs registered number 5,684. There are 200 motor trucks registered, and there would be more than double this number if English manufacturers could fill the orders of local agents.

Coal By-products.—A considerable number of the larger colliery companies in South Wales are laying down extensive plant for the recovery of by-products. The Powell Duffryn Company, the Ferndale Company, and the Blaenavon Company intend to erect plant for the extraction of gas tar and oils from coal; while the Cambrian Combine, in the Rhondda, has just spent £50,000 on plant for the extraction of tar and ammonia. The new plant consists of 50 ovens, and a large percentage of the gas created for heating the ovens will be available for lighting the town.

British Shipbuilding Record.—The shipbuilding returns for the United Kingdom for 1912 show another record in production. The total output has reached the unprecedented figures of 2,125,833 tons, as compared with 2,042,928 tons last year, an increase of 82,905 tons. The "blue riband" comes to the Tyne for the second successive year. The four leading firms and the amount of their individual production are as follows: Messrs. Swan, Hunter, & Wigham Richardson, Ltd., 126,152 tons; Messrs. W. Doxford & Sons, Sunderland, 92,481 tons; Messrs. W. Gray, West Hartlepool, 90,272 tons; Messrs. Workman, Clark, and Co., Belfast, 85,391 tons.

Estimated Output of American Motor-cars in 1913.— According to the "Automobile Trade Journal," the probable output of pleasure cars by United States manufacturers in 1913 is placed by a conservative estimate at 627,650, or more than twice the estimated output (viz., 250,000 to 285,000) for 1912. One of the largest companies has arranged to produce 200,000 cars, as against 75,000 in 1912. Although some of the most expensive types of car are being sold at an increased price owing to better finish and fittings, there are a greater number of machines now sold at reduced prices.

The Use of Cobalt in Steel.—On the recommendation of the Department of Mines, the Canadian Government has, according to a correspondent of the "Birmingham Post," appointed Dr. Herbert Kalmas, of the Kingston School of Mining, and several other experts, to undertake an exhaustive investigation into the possibilities of cobalt oxide for use instead of nickel in steel alloys. Experts of the Department who have been conducting experiments are satisfied that cobalt, which resembles nickel in almost all its properties, could easily be used instead of the latter, and should their contention be upheld it will mean the addition of another almost inexhaustible source of Canada's great mineral wealth. It is estimated that the cobalt obtained from the Temiskaming district of Ontario alone exceeds in value £2,000,000 per year, and owing to the present limited use for it there is an enormous accumulation,much of which is being wasted. Cobalt being almost essentially a Canadian product, very little investigation of its merits has been undertaken, miners and prospectors devoting their attention to the search for silver and other better known precious metals.

Residual Gas Products.—The report has just been issued of the Joint Select Committee of the two Houses of Parliament on Gas Authorities (Residual Products). The Committee are of opinion that some restrictions should be imposed upon gas undertakings, but are not prepared to grant all the restrictions asked for by the chemical manufacturers. In addition to working up their own residuals and purchasing the necessary materials the Committee further consider that one gas undertaking should be allowed to purchase the residuals of other undertakings in order to manufacture other products of the same kind as the purchasing undertaking is manufacturing from its own residuals, but this is subject to qualification. They consider that gas undertakings should, in addition to buying residuals from other gas undertakings, be authorised to buy from gas undertakings or elsewhere the materials required to work up the purchased residuals. They consider, however, that gas undertakings should not be allowed to manufacture chemicals exclusively from raw materials bought from sources other than gas undertakings, or in the manufacture of which the use of residuals produced by themselves or bought from other gas undertakings is merely subsidiary.

Coal Reserves in the United States.—The known coal fields of the United States embrace a total area, according to the United States Geological Survey, of 310,296 square miles, to which may be added something over 160,000 square miles of which little is known, but which may contain workable coals and about 32,000 square miles where the coal lies under heavy cover and is not considered available under present conditions. The supply of coal before mining began is estimated to have been 3,076,204,000,000 short tons, of which 1,922,979,000,000 tons were considered to be easily accessible and 1,153,225,000,000 short tons to be either so deep or the beds so thin that they are accessible only with difficulty. Classified according to the character of the coal, the original supply consisted of 21,000,000,000 short tons of anthracite, 1,661,157,000,000 tons of bituminous coal, 650,000,000 tons of sub-bituminous coal, and 713,590,000,000 tons of lignite the supply of bituminous coal being something more than that of all other grades combined. The total production of coal to the close of 1911 has amounted to 2,270,798,737 short tons of anthracite and 6,468,773,690 tons of bituminous coal, or an aggregate of 8,739,572,427 tons. This total production to the close of 1911 represents, including the waste of coal in mining, an exhaustion of the beds equal to 14,181,980,000 short tons, or somewhat less than 0·5 per cent. of the original supply. The annual rate of exhaustion at the present time, as represented by the production in 1910 and 1911, is 0·025 per cent. of the supply

Opening of the Enlarged Assouan Dam.—Egypt may in the near future look forward to increased prosperity, owing to the successful completion of the heightening of the great Nile dam at Assouan, which was formally opened by H.H. the Khedive on December 23rd. The Assouan dam was first brought into operation during the winter of 1902-3, having taken four years to construct, and the original outlay has already been earned many times over by the enhanced production of crops. It is approximately $1\frac{1}{4}$ miles across, and its wall was originally 82ft. wide at the river bed at the deepest points and 23ft. wide at the top, the dam rising approximately 128ft. above its foundations. It is pierced by 140 culverts 23ft. high by 6ft. 7in. wide, and 40 culverts 11ft. 6in. high by 6ft. 7in., the culverts being placed at different levels, and fitted with the free-roller "Stoney" sluices, which have played so important a part in the success of the dam. These were designed, manufactured, and installed by Messrs. Ransomes & Rapier, of London and Ipswich. The original pressure against the deep level sluices was about 210 tons. The increased storage requirements necessitated an additional height of dam of some 16ft. 5in., with an increased thickness of wall across the top of about 13ft. 6in., the present total height of the dam being approximately 144ft. at the deepest points. This has had the effect of increasing the pressure against the low-level sluices to approximately 308 tons. In spite of this enormous load, however, the sluices can easily be operated by one man, so as to regulate the discharge of water day by day.

METAL QUOTATIONS.

TUESDAY, DECEMBER 31ST.

Aluminium ingot	95/- per cwt.
„ wire, according to sizes, &c. ......from	112/- „
„ sheets „ „ ...... „	120/- „
Antimony ......£38 [illegible] – to	£40/–/– per ton.
Brass, rolled	9d. per lb.
„ tubes (brazed)	$11\frac{7}{8}$d.
„ „ (solid drawn)	$9\frac{1}{2}$d.
„ „ wire	9d.
Copper, Standard	£75/17/6 per ton.
Iron, Cleveland	67/9 „
„ Scotch	73/9 „
Lead, English	£18/10/- „
„ Foreign (soft)	£18/1/3 „
Mica (in original cases), small	6d. to 3/- per lb.
„ „ „ medium	3/6 to 6/- „
„ „ „ large	7/6 to 11/- „
Quicksilver	£7/8/6 per bottle
Silver	28[illegible]d. per oz.
Spelter	£26/7/6 per ton.
Tin, block	£229/10/- „
Tin plates	15/3 „
Zinc sheets (Silesian)	£29/17/6 „
„ (Stettin; Vieille Montagne)	£30/5/- „

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Removal of water from wet carbonised peat. Rigby & Testrup. 21748.
Steam pile drivers. Garvie. 25388.
Water discharge or steam trap for use with steam-heating systems. Raffensdorfer. 27336.
Processes for extracting metals from ores. Mackay. 27342 and 27345.
Steam generator furnaces. Caddy & Co. (Nottingham), and Rickards. 27432.
Carburetters for internal-combustion engines. Cross and Bainbrigge. 27442.
Process for the elimination and recovery of arsenic, antimony, copper, lead, zinc, sulphur, and other undesirable constituents of ores used in the construction of iron, spiegeleisen, and other iron manganese products. Brackelsberg. 27451.
Burners for heating the seams of tubes to be welded. Walber. 27472.
Valve mechanism of engines. Roberts. 27504.
Devices for regulating the speed of machinery. Siemens Bros. Dynamo Works, Ltd. 27588.
Profiling machines for metal. Hanson & Grohmann. 27596.
Conveying apparatus. Adkins & Lewis. 27682.
Clamps or couplings for pipes, rods, and shafting. Barber. 27825.
Internal-combustion engines. Carlton. 27833.
Method of melting metals and alloys. Wile. 27836.
Means for transmitting rotary motion. Jandus Arc Lamp and Electric Company, and Jones. 27840.
Process for producing clean or deoxidised metal surfaces. Hatfield & Yates. 27949.
Variable-speed gearing. Ravigneaux. 28034.
Lubricating arrangements for shaft or axle bearings. Spencer. 28056.
Treatment of steel turnings and shavings. Vickers, Ltd., Clark, and Dickenson. 28057.
Mechanical ore-roasting furnaces. Parent. 28078.
Bearings for mill rolls and pinions. Davies. 28260.
Manufacture of iron from scrap metal. Lake. 28279.
Methods of and apparatus for mining coal. Hoadley & Knight. 28388.
Cutting tools for metal and wood. Dobson. 28412.
Annealing pots used in the annealing of metallic sheets. Jones. 28561.
Steam steering gear for ships. Grieves. 28819.
Closing ferrules for sealing steam condenser tubes. Love and Eugene Brown. 28840.
Gas analysing apparatus. Ingeniorsfirma Fritz Egnell. 29211.

1912.

Compound internal-combustion engines. Pearson. 73.
Tool for truing up the faces of the bearing blocks or carriages which carry the crank shaft of an internal combustion engine. Austin. 117.
Spanners and wrenches. Robertson. 230
Pipe couplings. Taylor & Whyte. 836.
Manufacture of silicon or other steels. Williams & Brymbo Steel Company. 1293.
Piston-valve internal-combustion engines. Albion Motor Car Company, and Murray. 1429.
Means for operating the fuel spraying valves for internal-combustion engines. Blackstone, and Carter & Carter. 1827.
Roller bearings. Appleby. 1882.
Device for preventing derailment of railway vehicles. Schellerich. 3022.
Acetylene generators. Lucas & Egginton. 3810.
Means to be employed in the casting of moulds for casting ingots. Butler. 3872.
Bolts. Mayer & Daimler Company. 4310.
Sand-moulding machines. Strettles & Russell. 4565.
Sand-moulding machines. Pridmore & Pridmore. 4869.
Construction and method of fixing the guide blades and vanes of turbines. Morcom, and Belliss & Morcom, Ltd. 5155.
Internal combustion engines. Bellem & Bregeras. 5243.
Safety devices for the cages of lifts or hoists. Mallott & Mallott. 5611.
Rolling mills. Ludwig, and Mannesmannrohren Werke. 5650.
Process for manufacturing bolts and rivets by means of machines. Muller. 5767.
Pins for centring and guiding flasks and moulds. Valerius. 5799.
Valve mechanism for internal combustion engines. Harley. 5908.
Means for starting internal-combustion engines. Edkins and Edkins. 5915.
Chaplets employed in moulding boxes for casting metals. Grace. 6424.
Valves for internal-combustion engines. Holst. 6766.
Screw propellers. Di Fenile. 7070.
Governing mechanism for centrifugal compressors operating in parallel. British Thomson-Houston Company. 7363.
Signalling apparatus for use in screw-cutting lathes. Bennett and Fosbrooke. 7486.
Charging apparatus for shaft furnaces. Deutsche Maschinenfabrik. 7900.
Starting or reversing means for internal-combustion engines. Soc. Anon. Cantieri Officine Savoia. 8171.
Milling cutters. Koch. 8537.
Presses for working metal. Fried. Krupp Akt.-Ges. Grusonwerk. 10252.
Compressed air and vacuum brake mechanism particularly for high-speed railway trains. Vielmetter. 10973.
Gas analysis apparatus. Simmance, Abady, & Wood. 11664.
Safety starting device for internal-combustion engines. Hilton and De Wildt. 11917.
Change-speed gears. Lancia. 12494.
Reversing means for internal-combustion engines. Vollmer. 12700.
Variable-speed gearing. Ravigneaux. 12707.
Treatment of metals or alloys to render them ductile and malleable. Westinghouse Metallfaden Gluhlampenfabrik Ges. 12869.
Gas producers. Dowson & Mason Gas Plant Company, and Cunningham. 14894.
Ratchet wrenches and braces. Geist. 15259.
Machines for punching plates. Cameron, and John Cameron, Ltd. 16116.
Elevator safety devices. Mortenson. 16601.
Acetylene generator. Arnold. 18185.
Cooling of enclosed gears. Hennicke. 18315.
Propelling device for ships' boats. Aaron. 18419.
Dressing of tin-bearing ores. Bailey. 18490.
Nut locks. Edwards. 18831.
Turbines. Mossop. 18868.
Apparatus for starting internal-combustion motors. Closson and Miessen. 19037.
Tool grinders. Lumsden. 20439.
Brakes for railway wagons. MacClure. 20491.
Continuous lubricating device for bearing bushes. Aktiebolaget Separator. 21483.
Automatic couplings for railway vehicles. Heuser. 23281.
Luffing cranes. Imray. 24036.
Valves for steam. Kay. 24189.
Means for raising liquids and for pumping fluids of any kind. Duquenne. 25143.
Turbine blades. Imle. 25281.
Pressure regulating devices for ball grinding machines. Deutsche Waffenund Munitionsfabriken. 26556.
Smelting operations. Testrup & Rigby. 27150.

ELECTRICAL, 1911.

Electric furnaces. Testrup & Rigby. 19923.
Type-printing electric telegraph systems. Steljes. 20106 & 20107.
Electrically-operated time indicating devices. Aron & Harrison. 20268.
Means for and methods of clearing faults on alternating-current systems. Taylor. 27560.
Prepayment attachments for electric current limiting devices. Nordfeldt. 27801.
Electric regulating or equalising apparatus. Rankin & Chloride Electrical Storage Company. 28913.
Inter-communication telephone systems. Nash & Western Electric Company. 29027.
Electric ignition apparatus for internal-combustion engines. Cowcher. 29326.

1912.

Arc lamps. Burkitt. 4417.
Electric insulators. Bullers, Ltd., and Twiss. 6286.
Electrical condenser. A. C. Cossor, Ltd., and Stenning. 6987.
Inductor alternator. Podlesak. 6988.
Electric incandescent lamps. Weisse. 8058.
Terminals for electric conductors. Anderson & Fritts. 13111.
Devices for measuring electric resistances. Siemens Bros. & Co. 15362.
Electrodes for use in arc lamps. Low. 17678.
Receiving apparatus for electric waves. Schneider. 18806.

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WILLIAM H. FOWLER,
Wh. Sc., M.Inst.C.E.

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Electrolytically Deposited Copper Steam Pipes.

ALTHOUGH destructive explosions of boilers on board ship are comparatively rare, thanks largely to the stringent supervision exercised by the Board of Trade over materials and construction, numerous failures of steam pipes and connections are reported from time to time. The majority of these consist of fractures so trivial in themselves that on land they would pass as ordinary incidents of wear and tear. But on board ship a sudden escape of high-pressure steam may not only imperil the engine-room staff, owing to the confined space of engine-room and stokeholds, but if weather conditions are bad it may, by interfering with the propelling machinery, jeopardise the safety of all on board. For this reason special importance attaches to the steam connections, and it is with a view to diminish risk of failure that copper is so extensively used for steam pipes in marine practice. Its ductility and freedom from corrosion certainly appear to give it an advantage over steel, where racking stresses, such as occur from the movements of machinery on board ship, are concerned, but the numerous failures of copper pipes since the advent of high pressures have tended for some years to discredit the use of copper and led many engineers to adopt mild steel instead. Experience, in our opinion, justifies this choice, though probably the majority of sea-going engineers still pin their faith to copper. It is true that as regards corrosion it is less susceptible to ordinary wasting influences than steel, though in this respect it is not so immune as is generally supposed. The brazed joints of copper pipes are particularly liable, as Prof. Arnold showed several years ago in connection with a disastrous explosion on the s.s. "Prodano," to be deteriorated by fatty acids produced in boiler or steam pipes by the decomposition of organic oils, which under certain conditions effect an electrolytic change in the materials of the spelter or soldering material, the copper being converted into a spongy

mass filled with oxide of zinc and possessing a very low tensile strength. Again, pure copper is liable to rapid deterioration by the acid ingredients in certain forms of asbestos covering if it gets wet with sea water, and a disastrous explosion on board the s.s. "Orizaba" traced to this cause shows the importance of screening such covered pipes from dampness of this kind. Liability to corrosion by fatty acids is not the only defect to which brazed joints are liable. The brazing itself may be deteriorated if the heat is not skilfully regulated in the brazing process, and unfortunately such defects are not easily detected, while they appear to develop with age and service, since joints which have withstood a severe hydraulic test and been carefully inspected when new, have afterwards failed without warning while working at less than half the test pressure. The use of solid drawn pipes removes the risks incidental to a brazed joint, but even they are liable to have concealed flaws as a result of blow holes in the billet and are not very suitable for bends, owing to the drawing out of the material on the outer radius when being formed into shape. Sometimes copper pipes are formed by a process of electro deposition on a mandrel and such a process it might be thought would remove all possibility of latent defects, because electrically-deposited copper is of exceptional purity, but experience does not support this view. Simple electro-deposition, as a matter of fact, would produce a material quite unsuitable, because copper so formed has little or no tenacity. This characteristic is only secured by submitting the layer of copper on the mandrel to the pressure of an agate burnisher which travels backwards and forwards along the mandrel as the latter rotates in the depositing bath. This motion is usually so regulated that the layer of deposit never increases more than about $\frac{1}{700}$th of an inch without coming under the action of the burnisher, which imparts a high tenacity to the copper. Ordinarily the tenacity so produced is about 26 tons, but specimens have been so produced with a tenacity of over 40 tons. Notwithstanding the theoretical perfection of such pipes, many have failed in practice. A recent example is furnished by Report 2,163, just issued by the Board of Trade, on the bursting of an electro-deposited copper pipe on board the s.s. "Skipton Castle." The pipe, which was 5½in. bore and ·232in. thick, ripped longitudinally for a length of about 20in. without warning. Careful examination after the disaster revealed a number of fine cracks which penetrated some distance into the plate, while photo-micrographs showed the material to be coarsely crystalline in structure and unsuitable for the alternating stresses to which pipe connections are inevitably subjected on board ship. The report suggests that the crystallisation was due to the material having been subjected to too high a temperature or to a moderate temperature for an unduly long period. That such treatment may produce crystallisation is true —for which reason, it may be stated in passing, copper pipes should never be used for superheated steam —but there was no direct evidence it had been so treated, and those who bent the pipe when new in 1906 are stated to have subsequently annealed it and tested it by hydraulic pressure to 400lbs. on the inch to the satisfaction of one of Lloyd's surveyors, the working pressure being 180lbs. It is impossible to say how long the minute surface cracks, found after the accident, had existed, but it is difficult to think the crystallisation was due wholly to working conditions, for the bend was of large radius and the general arrangement of the pipes satisfactory, and as an alternative explanation we suggest the crystallisation may have been caused by the manner in which the pipe was made, for von Hübl has shown* that the character of electrolytically-deposited copper depends not only on the burnishing of the deposit on the mandrel, but also on the strength of the electric current and the strength of the copper sulphate solution used. With weak currents the deposit is always liable to be coarsely crystalline and brittle, and though tenacity increases with the strength of the current, the increase is accompanied with a loss of ductility. Thus, to quote Hübl's figures, he found that with a 20 per cent. bath of copper sulphate a current of 0·61 amperes per square decimetre yielded a copper which broke under a stress of 18·0 tons with an elongation of 27 per cent., while a current of 2·22 amperes per square decimetre gave a metal with a tenacity of 23·6 tons, but an elongation of only 16 per cent. The metal with greatest elongation, viz., 33 per cent., was obtained from a 15 per cent. solution and a current of only one ampere per square decimetre, but, on the other hand, its tenacity was only 17·3 tons. It would appear from these tests that the character of electrolytically-deposited copper may be affected considerably during formation, unless care is taken to maintain the current and strength of the bath constant. In this way defects of manufacture may creep in which it is practically impossible to detect afterwards. For this reason alone, it appears to us, engineers are justified in viewing electrolytically deposited copper steam pipes with mistrust. It should, however, be stated in justice to the pipe that failed that tensile tests by David Kirkaldy & Co. of strips cut from the neighbourhood of the rupture showed it to be of satisfactory quality originally. They expressed the opinion that the surface cracks and circumstances of failure indicated that the crystalline structure revealed by the micrograph was caused by fatigue during service—a view, it may be added, in which the Board of Trade Surveyor who investigated the case concurs, though there is a difficulty in reconciling it with the evidence of the engineers on the vessel, who all averred that no perceptible vibration was discernible even in heavy weather. The Report states that such vibration is inevitable, but if this is so it is only another argument against the use of such pipes, and the logical conclusion is that the Board of Trade should refuse to pass them. It does not, however, take this firm stand, but contents itself with pointing out that owing to the frequent failures of copper steam pipes in the past "lap-welded wrought-iron or solid-drawn mild-steel steam pipes have largely come into use and that so far the results have been good," adding "that owing to the increased strength of these steel pipes the cast-iron valve chests and junction pieces require to be of ample strength to resist expansion or vibratory stresses." In this connection it may be convenient to point out that pipes even of copper are much stiffer than is generally supposed. The deflection of a pipe with diameters D and d for a given load when subjected to bending or torsion or both combined is the same as that of a solid bar whose diameter is equal to the $\sqrt[4]{D^4 - d^4}$. To illustrate this with a concrete case, if a pipe is, say 8in. diam. outside and 7½in. inside, then as regards rigidity it is practically the same as a solid bar about 5½in. diam., and such a bar, it is needless to say, would have considerable stiffness even if of copper. For this reason bends in any case should be made with as large a radius as possible. The effect of temperature on the strength of copper is also a point that is sometimes overlooked, and hence it may be worth noting that some tests made at the National Physical Laboratory with pieces cut from the burst pipe showed that for an increase from ordinary atmospheric temperature to that corresponding to a steam pressure of 180lbs., viz., 380° Fah., the tenacity was diminished from about 14 tons to about 10·75 tons per square inch, and attended also with a slight reduction in ductility.

* Electro-Metallurgy, Messrs. McMillan and Cooper. C. Griffin & Co.

ELLIOTT'S FEED-WATER HEATER.

THE feed-water heater illustrated in the accompanying sectional views, the invention of Mr. W. S. Elliott, 6,907, Susquehanna Street, Pittsburg, Pa., U.S.A., has been designed to provide a heater having a plurality of heating compartments, which compartments may be operated simultaneously, or any compartment may be shut off for cleaning, repairs, or for varying the capacity, without interfering with the other compartments.

The casing is provided with an interior, transverse partition extending the full width and length of the casing and dividing it into the two compartments A and B. The casing is provided at one side with the steam entrance chamber C. From this chamber a port opens into the compartment A, and another port opens into the compartment B. Each of these ports is arranged to be controlled by a valve D, which is mounted in a suitable valve cage, and is carried by a stem E which extends transversely across the interior of the casing and through the opposite wall thereof, being provided at its outer end with a hand wheel F. The sealing face of each valve is provided with a plurality of ribs or corrugations G, which act as separators for the oil and other foreign matter entrained in the entering steam. To catch this separated oil or other matter, a pocket H is formed below each valve, shown in Fig. 2, and having an outlet at its bottom.

discharge into a receiving pan R, which has a saw-toothed upper edge. Placed below this receiving pan are a series of two or more relatively shallow trays, the upper tray receiving the overflow from the saw-toothed edge of the pan R and having openings therein which discharge into the lower tray. From this lower tray the overflowing water passes through the steam filling the upper portion of the compartment. The upper portion of each compartment is provided with a steam outlet S controlled by a valve T actuated by a stem U, and which may occupy a central position between the two passages S, or which may be moved to close either one of these passages.

Each compartment is provided with an outlet port V, opening into an outlet connection, and which is controlled by a sliding valve W similar to the valve T just described. In order to prevent back flow from the outlet connection, each port V is provided with a check valve X. The outlet connections extend from outlet chambers Y, each of which has an inlet opening below the water line, and also has a short pipe extending from its top upwardly into the compartment above the normal water line. The check valves, as will be seen, assist the float-controlled inlet valves in maintaining a practically equal level in both compartments, since the water from the chamber having the higher water level will tend to hold the check valve at the outlet of the other chamber closed as long as any difference in water level remains. Each compartment is also provided with an overflow pipe Z, which extends within the compartment and nearly across the same,

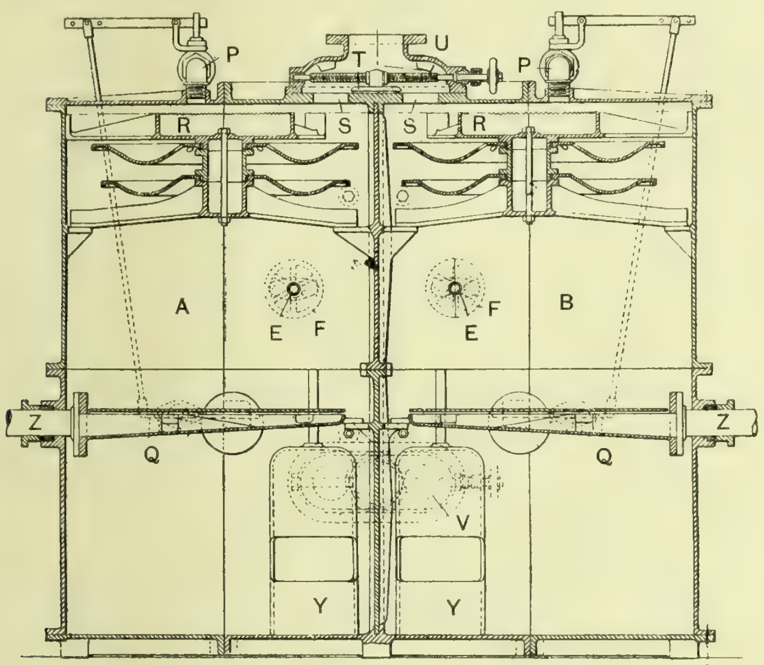


Fig. 1.

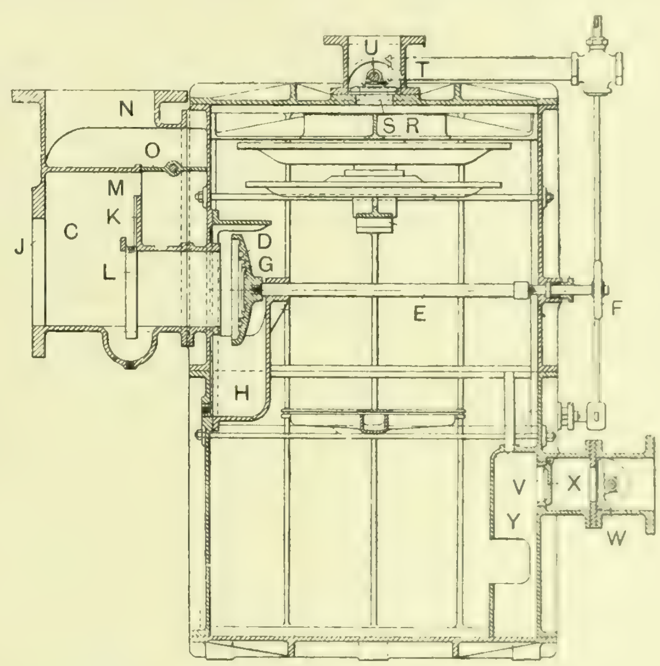


Fig. 2

SECTIONAL VIEWS OF ELLIOTT'S FEED-WATER HEATER.

The steam enters the chamber C at the port J, and when the heater is used in connection with a steam heating system there is placed opposite this port (see Fig. 2) a baffle plate K having a corrugated surface, to also act as a separator. At the lower edge of this baffle is a pocket from which leads a discharge pipe L which discharges into a pocket at the bottom of the chamber C. When not used in connection with a steam heating system, the separator plate K can be omitted. The chamber C is also provided with a passage M above the upper edge of the baffle K and leading to an outlet passage N which is controlled by valve O. When the heater is used in connection with a steam heating system, the passages N will connect to such system; if not used in connection with a heating system, the passage will lead to the atmosphere. The valve O provides means for regulating the amount of steam which may be passed into the heater.

The water to be heated enters the compartments A and B by means of the inlet pipes P, one of which communicates with each of the compartments at its upper end. Each of these pipes is provided with a control valve whose stem has actuating connections with a pivoted float lever Q carrying a float, there being one of these floats in each of the compartments, and each float controlling the valve of the inlet pipe for that compartment. Each inlet pipe P is arranged to

with laterally extending branches. The portions of these outlet pipes within the compartments are in the form of troughs having openings at the sides between the cover plates immediately above them. The openings into these troughs are at substantially the normal water level of the compartments, which level is maintained by the action of the float-controlled inlet valves in combination with the check valve X. These troughs form a means for removing and carrying off scum from the top of the water. The operation will be readily understood from the foregoing description. It will be seen that either one or both of the compartments may be simultaneously in use; or that either compartment may be closed off while the other compartment is out of use for any reason.

Status Prize.—The Council of the Society of Engineers (Incorporated) may award in 1913 a premium of books or instruments to the value of £10. 10s., for an approved essay on "A scheme for the registration of Engineers, including particulars concerning the registration of Engineers in British Colonies and foreign countries." The Council reserve the right to withhold the premium if the essays received are not of a sufficient standard of merit. The competition is open to all, but, before entering, application for detailed particulars should be made to the Secretary, 17, Victoria Street, Westminster. The last date for receiving essays is May 31st, 1913.

LARGE TURBO UNITS.*

BY J. P. CHITTENDEN.

THE first practical steam turbine driving an electrical generator was built by the Hon. (now Sir) Charles Parsons in 1884. Although this machine had only an output of 4 kw., with the consumption of 200lbs. per kilowatt-hour, it may be considered the start of the steam turbine industry in this country, as applied to the generation of electricity. This turbine, working under non-condensing conditions, with a boiler pressure of 60lbs. per square inch, gave an efficiency of only 15 per cent. To-day, with machines of similar type, but of a more elaborate construction and greater output, an efficiency of over 70 per cent. is obtainable. This progress is no doubt due primarily to the general increased demand for electrical energy, and the natural desire for greater efficiency. This latter demand has led to the introduction of larger units; as it will be seen from Fig. 1, curve A, that in the case of a 1,000 kw. machine the average efficiency is only about 57 per cent., whereas in a machine of 10,000 kw., or over, an efficiency of 70 per cent. is quite a reasonable proposition.

For many years the question of large output from the electrical end was a difficult one, but now, owing to improvements in design and construction, turbo-generators of large outputs and speeds are practicable. It is not more than four or five years since a 1,000 kw. machine at 3,000 revs. per

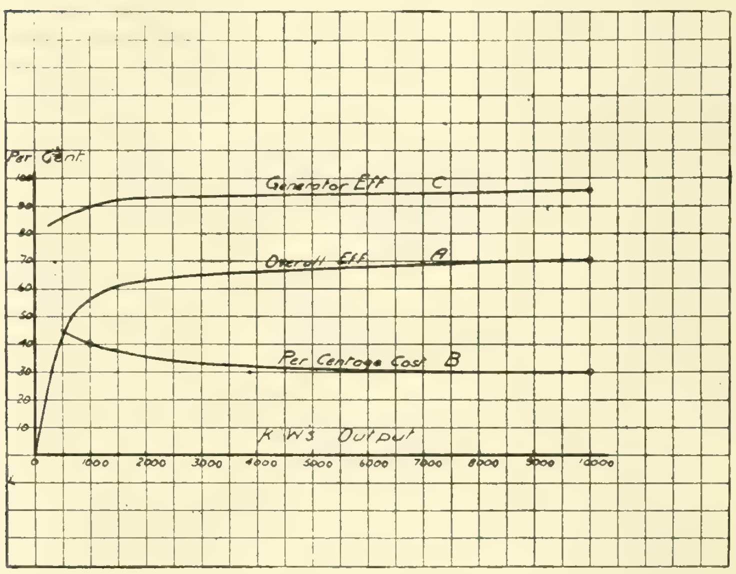


FIG. 1.

minute was considered more or less an impossibility, but to-day electrical generators are being designed and constructed capable of developing an output of 6,000 kw. to 7,000 kw. at a speed of 3,000 revs. per minute, and the steam turbine builder is now in the position of having to look to his laurels with regard to the question of output, especially in the case of turbines constructed on the single-flow principle, for with the materials at present at his command, it is a difficult proposition to build any type of steam turbine developing over 6,000 kw. at a speed of 3,000 revs. per minute, or a machine of 15,000 kw. at 1,500 revs. per minute.

Turbine Efficiency.—As previously explained, the question of efficiency is of vital importance in the case of large power machines, and before considering a few of the best known turbo-generating sets installed in various parts of this country, it would be interesting to look into those points of design which control the over-all efficiency of the turbine itself. There are two principal reasons why higher efficiencies are obtained with machines of large output.

The first reason is purely a commercial one, and is controlled by the question of the price obtainable for the size of unit in question. It will be seen from the Fig. 1, curve B, that in the case of the small machines, a far greater percentage of the total cost is taken up in the production of those parts which do not directly affect the internal efficiency of the machine, that is to say, portions of the turbine, such as governor gear, thrust, steam range, bearings, &c., cost a good deal more to produce (compared with the body, rotor, and blading) in the case of a small machine than in a large one. It will be seen from this curve, in the case of a 500 kw. machine the percentage of the total cost of these parts is 45 per cent., whereas in a 10,000 kw. turbine the percentage is only 30 per cent., and from this it follows that it is impossible to manufacture small machines of high efficiency unless an exceptionally high price is obtainable.

The second reason for better efficiency in the larger machines is purely a technical one, and to understand this, one must consider the fundamental principles which control steam turbine design. Taking 1lb. of steam at a given initial pressure, there is a definite amount of stored-up or potential energy, and by expansion of this steam to a lower pressure through suitable passages, or blade rings, a certain amount of work can be done by the extraction of the kinetic energy thus acquired. This is due to the change effected in the momentum of the steam in passing through the blades, and this change of momentum per second is equal to the force necessary to produce reversal of direction, and can be calculated from the following formula:—

C = Exit velocity from fixed blades.
n = Radius of application fixed blades.
C_1 = Exit velocity from the moving blades.
n_1 = Radius of application moving blades.
a = Constant blade angle.
w = Angular velocity.
W = Work done in foot-pounds per second in moving row per pound of steam.

$$W = \frac{w}{g}\,(C \times Cos\,a \times n + C_1 \times Cos\,a \times n_1 - n_1^2 \times w)$$

Between the extreme pressures under which modern turbines are designed to work, there is available a considerable amount of heat per pound of steam, and the efficiency of the machine depends upon the manner in which this heat is divided up.

To obtain the maximum efficiency from the heat available for a given pressure fall, the steam velocity must bear a certain ratio to the blade velocity; this ratio is shown from the curves given in Fig. 3 (A, B, C, and D), and varies according to the type of blading employed. Curve A represents a one-row or simple velocity wheel in which the maximum efficiency 81 per cent. occurs at a ratio of C/u 2·0. On curve B a two-row Curtis or velocity compounded wheel is shown. In this case the maximum efficiency 67 per cent. is at a ratio of 4·5. The three-row Curtis wheel is shown by curve C, where with a ratio of 6·5 the maximum efficiency is 51·0 per cent., and lastly the curve D shows the impulse reaction (or perhaps better known as Parsons' blading), where a maximum efficiency of 84 per cent. is obtained when running at a ratio of steam speed to blade speed of 1·4.

From this one can see that if the maximum efficiency is desired, the steam speed must bear a certain ratio to the blade speed; and with a given number of revolutions per minute, number of stages, and total pressure range, the radius of application (or mean diameter of blading) must remain constant, and the output of the machine is dependent directly upon the length of blade.

Taking as a general example any type of machine should it be found necessary to have a blade speed, say, of 300ft. per second to give the desired efficiency, and a blade height of 1in. for an output of 1,000 kw., to increase this output to 5,000 kw. the blade height will be approximately 5in., providing that the blade angles and number of stages are constant in both cases. This applies for any type of machine, where full peripheral admission is used, and from this it follows that for a given speed and efficiency the mean radius of application, and the number of stages, must remain constant, no matter what the output of the machine may be. So that for a turbine running at a given speed there is a certain relation between the number of stages, the mean radius of application, and driving force to give the required blade efficiency ratio, or in other words, the number of stages (or pressure falls) represent the division of the work through the turbine and

$$f \times N \times r = \text{constant}$$

where

f = force applied at a given radius.
N = number of stages or pressure falls.
r = the radius of application.

* Abstract of paper read before the Rugby Engineering Society, Jan. 7, 1913.

Thus it is possible to have one stage with a large radius, or many stages with correspondingly small radii of application, and still keep $f \times N \times r$ constant.

That by increasing the number of stages is beneficial to the over-all efficiency is shown by the following: Compare the case of a single-stage machine to a two-stage machine, with an individual blade efficiency in each case of 70 per cent., the one-stage turbine will have an over-all blade efficiency of

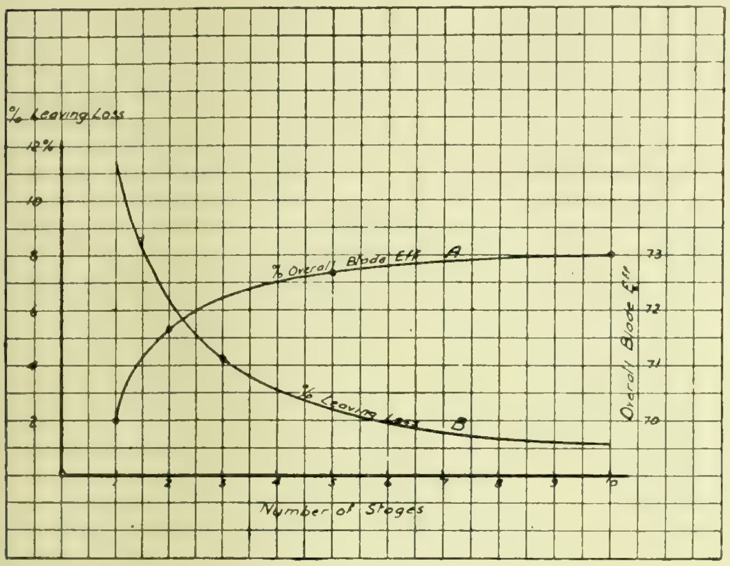


FIG. 2.

70 per cent., whereas in the case of the two-stage machine the over-all blade efficiency is 71·6 per cent.

The explanation of this gain in over-all efficiency is as follows: Taking the case of a turbine where the total heat at the initial pressure is 1,200 heat units, of which 300 are available for useful work due to adiabatic expansion; with the single-stage machine having an individual blade efficiency of 70 per cent., 210 of these heat units are used, and 90 heat units are rejected, giving an over-all blade efficiency of 70 per cent. But in the case of the two-stage machine, with 150 heat units available for the first stage, assuming the same individual blade efficiency, 105 are effectively used, the remainder (45 heat units) being rejected to the second stage (in the form of carry-over velocity and gain due to superheating), a percentage of these 45 heat units are available for useful work in the second stage, and combined with the 150 heat units remaining, give a total of 157 heat units. Taking 70 per cent. of these as being effectively used, then the useful work of the second stage equals 109·9 units, and the over-all blade efficiency equals 71·6 per cent.

TWO-STAGE TURBINE.

First Stage :—

Heat available = 150. Heat used $\frac{150 \times 70}{100} = 105$.

Heat rejected = 45.

Second Stage :—

Heat recoverable from first stage = 7. Heat available = 150.
Total heat available = 150 + 7 = 157.

$$\text{Heat used} = \frac{157 \times 70}{100} = 109\cdot9 =$$

Heat used in first stage = 105
" " second " = 109·9

Total = 214·9

$$\therefore \frac{\text{Heat used}}{\text{Heat available}} = \frac{214\cdot9}{300}, \text{ overall blade efficiency} = 71\cdot6\%.$$

It will be apparent from this that the more stages employed, the greater the overall blade efficiency of the turbine within limits, dependent upon the type of machine and the speed. In Fig. 2 curve A shows the overall blade efficiency with stages varying from one to ten. In the case of one stage overall efficiency is 70 per cent., and with ten stages an efficiency of 73 per cent. is obtained with the same individual blade efficiency. As seen from this curve, there is a certain point where increasing the number of stages does not give sufficient gain in economy to justify the increased cost in production, so that in designing a machine to give the maximum efficiency within commercial limits a definite number of stages are used, varying according to the type of machine and speed at which it is run. The following table gives the maximum number of stages for various types and speeds, bearing in view both the commercial and technical side of the question.

Type.	1,500 r.p.m.	3,000 r.p.m.
Multi-stage Simple Impulse ...	14 to 16	8 to 10
Multi-stage Compound Impulse...	4 to 6	2 to 3
Multi-stage Pure Reaction* ...	70 to 80	40 to 50

* Blade couples.

Leaving Losses.—The number of stages have also a direct influence on the leaving loss at the last row of blades, as it will be seen from Fig. 2, curve B (assuming a constant blade angle), the percentage decrease due to increasing the number of stages from one to ten is 10·5 per cent., and that after a certain point there is no appreciable reduction in the leaving losses, this bearing a definite relation to the position of maximum overall blade efficiency. The minimum leaving loss for a given blade velocity can be obtained from

$$\frac{(U \times Tan\ a)^2}{500\cdot0 \times H} = \text{percentage loss.}$$

Where U = Blade speed in feet per second.

a = Angle of outlet.

H = Total B.T.U.'s available due to adiabatic expansion from initial to final pressure.

From the above formula it will be seen that the minimum leaving loss depends upon the blade speed and angle of outlet, and is irrespective of the type of turbine. Leaving losses in machines of large output should not exceed 2 per cent. at full load if the overall efficiencies given in Fig. 3, curve A, B, C, and D, are to be obtained, in Fig. 4, curve A, B, C, are shown the percentage loss of various blade speeds and outlet angles.

Blade Losses.—The internal blade losses in the turbine may be divided up into: (a) The friction of the steam in the

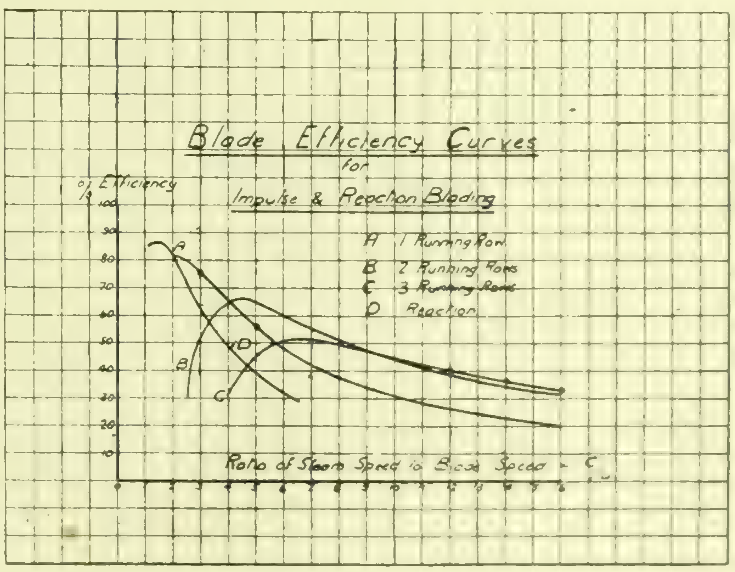


FIG. 3.

steam path; (b) angle at which the blades are set; (c) spilling and shock losses.

The first loss (a) is by far the greatest, and depends largely upon the velocity at which the steam travels across the blades, and with the normal range of steam speeds used this loss varies from 10 to 20 per cent. This, however, may be to a small extent reduced by the finish of blade surface, and from some recent experiments a highly finished blade

was found to be about 3 per cent. better than the ordinary commercially-finished blade.

With regard to the width of blade there is no definite rule, but the steam path should be kept as short as possible so as to reduce the surface friction to the minimum. This minimum width depends to a large extent upon the mechanical construction of the blade, method of fixing, and unsupported length of blade and speed.

With regard to the maximum blade length for a given blade width, it is usual in practice to allow a ratio of

$$\frac{\text{Blade length}}{\text{Blade width}} = 9 \text{ for reaction blading}$$

and 12 for impulse blading.

It is not always possible to work with this ratio, as it would entail too many standard blade sections, and in some cases extremely narrow blades, but it may be taken rather as a ratio not to be exceeded, for if so, there is a likelihood of vibration being set up in the blades themselves, and consequent weakening at the roots and shrouding.

The second blade loss (*b*) is that of the angles of inlet and outlet, for to obtain maximum efficiency it follows that there must be complete reversal of flow in the blade path, or, in other words, the steam must enter and leave the blade parallel with the plane of rotation—this, however, is impossible, as it would mean a blade height of infinite length, so that it remains to determine upon the smallest angle that

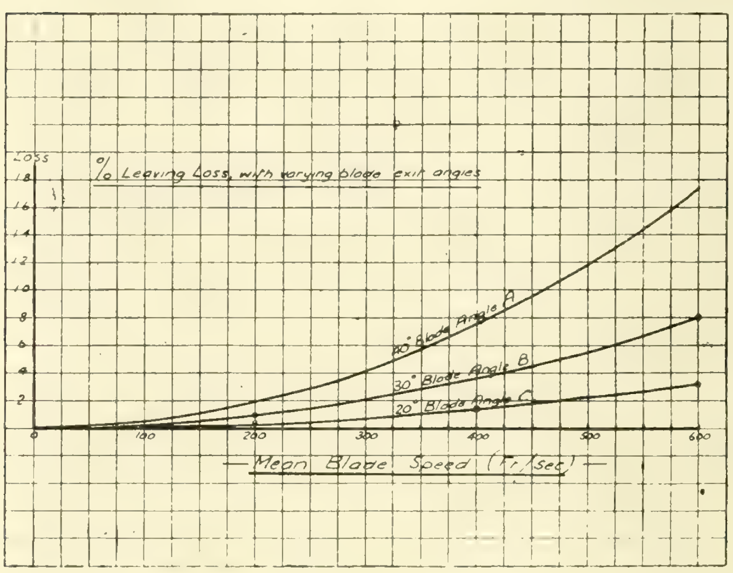


FIG. 4.

complies both with the commercial and technical considerations.

It has been found by De Laval and many other experimenters that the most efficient angle of exit, no matter what type of machine, is approximately 18° to 20° both for fixed and moving blades, and any advantage to be gained by making that angle less is neutralised by the increased losses due to crushing of exit path, extra length of blade, &c. The inlet angle of the blade is not such an important matter, for as long as ample provision is made to ensure the steam striking the inside edge of the blade, and an angle of shock up to 12° may be given without a detrimental effect on the efficiency.

Spilling and shock losses (*c*) are hardly a point to be raised specially in the case of large turbine designs, as they equally apply to all sizes of machines, and are really a question of care in the design of blade heights, clearances, &c.

Leakage Losses.—Leakage losses throughout a turbine can be reduced to a large extent by careful design and workmanship, but in many cases by decreasing these losses the reliability is affected. The parts at which these leakage losses take place vary according to the type of machine; in the case of the pure reaction machine, the principal leakage losses are those due to the clearance which must necessarily be allowed at the blade tips—fixed and rotating—and in the case of very small machines the clearance area is a considerable percentage of the total effective area.

This leakage of the steam through the clearance spaces may at first seem to cause a great loss in efficiency, but as the pressure fall across the blade rows is very small (being only half of that of an impulse machine with a corresponding number of rows), it follows that this leakage does not affect the overall efficiency of the machine to any extent, and further, any steam passing through the clearances enter the succeeding blade row in the form of useful work. The steam passed by this clearance space can be calculated from the following formula:—*

$$W = 68\,A.C.\,\frac{\sqrt{P_1\left(1 - \frac{1}{r^2}\right)}}{V_1\,(N + Log_e\,r)}$$

Where

W = Pounds of steam per second.
A = Areas in square feet through the labyrinth.
N = Number of baffles.
$r = \dfrac{P_1}{P_2}$ where $\begin{cases} P_1 \text{ Initial pressure.} \\ P_2 \text{ Final pressure.} \end{cases}$
V_1 = Specific volume of steam at P.
C = Coefficient of discharge.

With regard to the reduction of these clearances without impairing reliability, it will be seen from the formula given that the leakage varies approximately inversely as the square root of the number of baffles, so that by increasing the number of baffles, and the selection of a suitable ratio between blade height and clearance space, these losses can be made a negligible quantity.

With all impulse types of machines the steam leakage takes place between the diaphragm plates and turbine shaft, and as the number of stages in most cases is considerably less in the impulse than in the reaction types, the pressure fall across these glands must be greater, and care must be taken that sufficient number of labyrinths are employed to compensate for this, as, of course, the actual clearance must be kept the same to obtain the same reliability as on the reaction type. To overcome this difficulty the gland is often made of the floating type, from soft bronze or Perkins metal, and a series of 12 or more V-shaped grooves turned so as to form the labyrinth.

Frictional and Mechanical Loss.—These losses depend largely upon the internal finish of the machine, and although it is impossible to reduce them to any great extent, good workmanship will cut them down to a minimum, especially in the case of the impulse type. The question of frictional losses due to the rotation of bladed discs in steam is not one that allows of an easy solution, as it not only depends upon the finish of the disc and blades themselves, but on their general contour and arrangement of clearance spaces. From Prof. Stodala, Odell, and many other experimenters, it was found that the steam friction of bladed discs depends upon the surface, density and temperature of the steam, and speed of rotation. The percentage loss due to steam friction of discs may be found from the following:—

$$E = \frac{C \times d \times r^5 \times w^3 \times 100}{\text{B.H.P.}}$$

Where

C = constant dependent upon steam temperature, &c.
d = density of steam.
w = angular velocity.
r = radius.
E = percentage loss.

The percentage loss due to the blades varies directly as their length, and this loss can be obtained from the formula:

$$e = \frac{c \times v \times l \times d \times \sqrt{r_1} \times 100}{\text{B.H.P.}}$$

Where

c = constant dependent upon steam temperature.
v = mean blade velocity.
l = blade length.
d = density of steam.
r_1 = mean radius.
e = percentage loss.

* H. Martins. Formula for Labyrinth Glands.

These losses may generally be taken in well-designed machines of large outputs as varying from 2 to 3 per cent., but are, as previously explained, controlled to a large extent by the conditions under which the turbine has to work.

With regard to the mechanical losses, these may be divided into (*a*) losses from bearing friction which are dependent upon speed, weight, and lubrication, and (*b*) losses due to power required by governor, oil system, &c. These combined losses are a varying percentage of the output, and may be taken as 3 to 4 per cent.

Generator Losses.—With regard to the generator losses, these are shown in Fig. 1, curve C, for the various outputs.

General Design and Construction.—Turbines of large output may be divided into two classes, *i.e.*, those which are designed with one type of blading throughout, or those which embody two or more types. The simple types are either built on the Parsons, Rateau, Zoelly, or Curtis principles, and the compound types usually embody a combination of a Curtis disc for the high-pressure end, together with Parsons, Rateau, or Zoelly blading for the low-pressure portion of the turbine.

These two types may again be sub-divided into either single or double-cylinder machines. With the single machine the blading is arranged all on one shaft, but in the case of the double-cylinder machine the turbine is split into two separate portions which are placed in tandem with a coupling and bearing between the high and low-pressure portions. This method of construction has, up to the present time, only been employed in machines of the simple type, where the output and speed have been such as to require an exceptionally large number of stages to give the necessary efficiency. By this arrangement it will be seen that double the number of stages can be used without impairing the reliability of the machine.

(*To be continued.*)

IMPORTANCE OF ATTENTION TO ENGINE DETAILS.

THE extent to which serious breakdowns of steam engines spring from the failure of comparatively insignificant details is well known to those whose duties bring them into extensive contact with failures of this kind, though it is not so generally recognised by power users as is desirable, and an instructive illustration of the need for constant alertness in respect to incipient flaws in moving parts is given in the current issue of "Vulcan," the official organ of the Vulcan Boiler and General Insurance Company, which we take the liberty of reproducing.

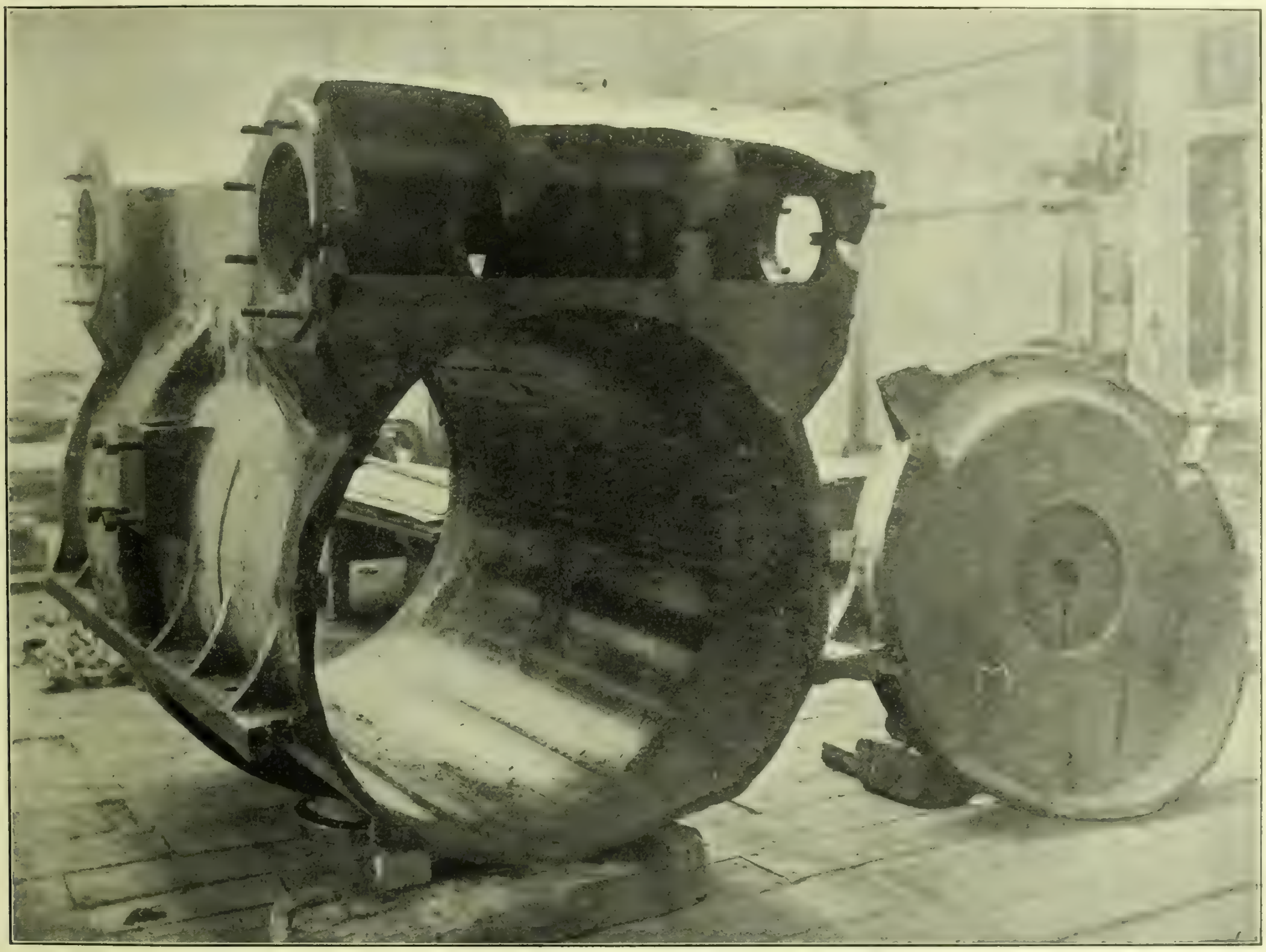


FIG. 1.—STEAM ENGINE BREAKDOWN FROM FAILURE OF CONNECTING-ROD STRAP. VIEW SHOWING BROKEN CYLINDER AND FRONT END, REVERSED

The breakdown in question, which was of a very destructive and costly character, as will be seen from the views on this and the following pages, was due primarily to the failure of the strap at the crank pin end of the connecting rod. The engine was of the usual cross-compound type with cylinders of $24\frac{3}{4}$in. and 49in. diam. by 5ft. 6in. stroke, running at 45 revs. per minute with a boiler pressure of 120lbs. The high-pressure cylinder was fitted with Corliss trip gear, and the low-pressure with circular slides, one at each end of the cylinder. The power was transmitted by gearing, and under ordinary working conditions indicated about 700 h.p. The failure of the strap ended in the practical wreckage of the low-pressure side of the engine. The released connecting rod was struck by the low-pressure crank, which was still being carried round by the action of the high-pressure side, and the rod was thrown into a vertical position hinging upon the crosshead pin. It remained in this remarkable position unaided, as will be seen in the photograph. The low-pressure cylinder, piston, covers, &c., were broken, the bedplate was damaged at the cylinder end, the crank was twisted round the shaft, the crank pin bent, the connecting rod damaged, and considerable other minor damage was done. Examination of the connecting rod strap showed that it was flawed across a section passing through the hole made in it for the crank pin

lubricator, and from the appearance of the fracture it was evident that the flaw had been in existence for some time. In fact on one side of the hole it had so completely severed the section that it was difficult to understand how it had escaped detection by the engine attendant when cleaning this part, as he must have done hundreds of times. The breakdown, our contemporary observes, shows the necessity when overhauling brasses and other moving connections of carefully examining all straps, bolts, screws, cotters, &c., before replacing them, to be sure that none of them are flawed.

MAKING BASIC OPEN-HEARTH STEEL FOR CASTINGS.*

BY H. F. MILLER, JUN.

For some years the prejudice against basic open-hearth steel for castings has been gradually decreasing. Still, many consumers and engineers cling to acid steel for castings because of the claim made that the castings are more free from blowholes and sponginess. Acid steel has been used for castings for a much longer period than basic steel and, therefore, the melters having had longer experience in acid practice for castings, had it well in hand when basic steel was first tried for that purpose.

The heat should be melted down as speedily as possible so as to prevent excessive oxidation. The hearth of the furnace, however, is a decisive factor in the production of solid castings. First, the manufacturer should know the size of the heats he intends to make constantly. Then he should have his furnace built for that size heat. The hearth should be of dimensions different from those of a furnace making ingot steel, that is, the bath should be deeper and should have less surface area. A shallow bath permits the slag to come out soon after the steel commences to flow and prevents the additions from going into the steel, or an even distribution in case the additions have been put in hurriedly.

Under this head comes the very poor practice of making small heats in hearths of a much larger capacity. For example, if a 25 or 30 ton furnace is in use and only 12 to 15 tons of metal are charged per heat, the proportion of heats that will be wild or show signs of wildness sometime during the pouring will be comparatively large. Whereas, when charged to capacity, a heat showing signs of wildness will be a rare occurrence.

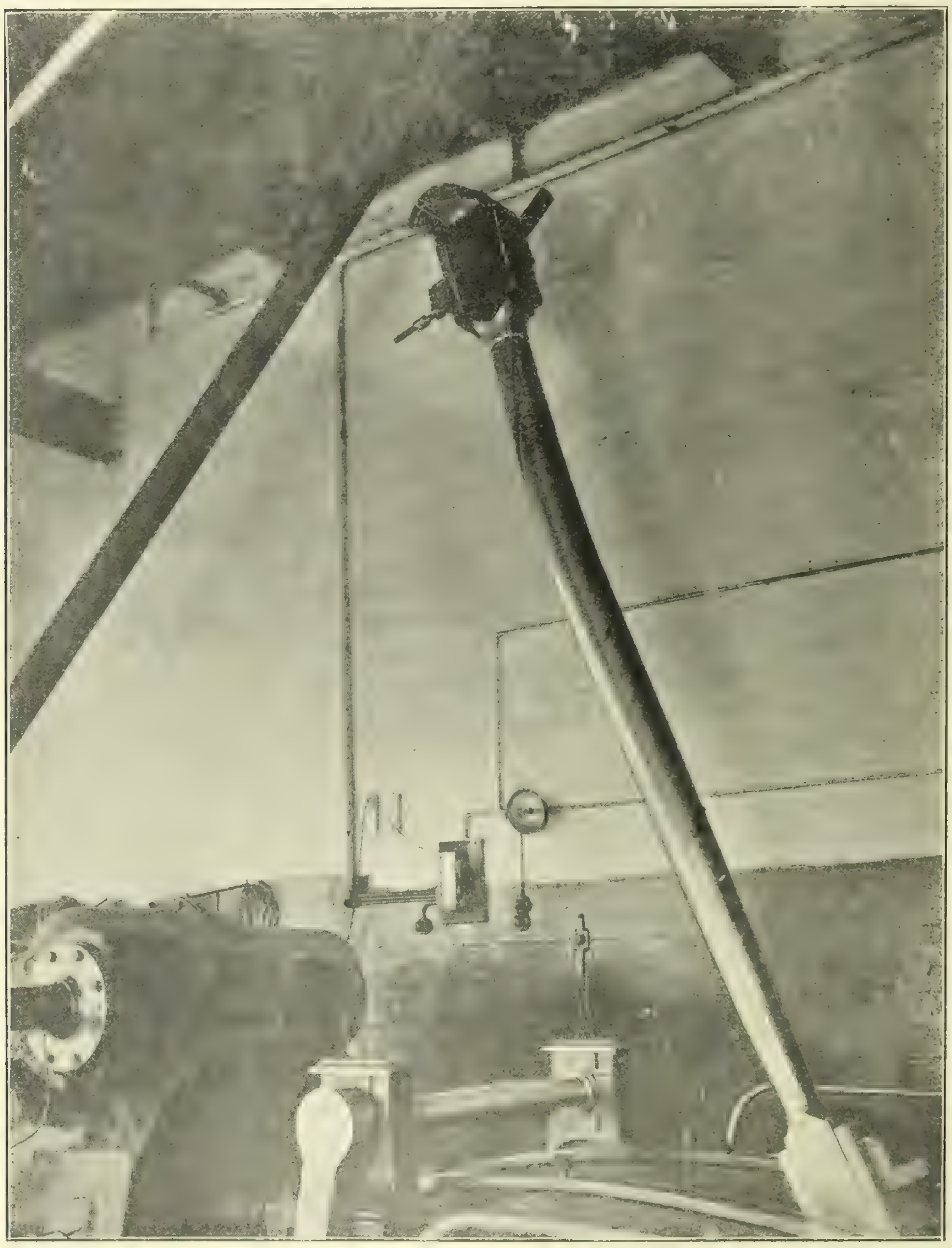


FIG. 2. STEAM ENGINE BREAKDOWN. VIEW SHOWING POSITION OF CONNECTING ROD AFTER BREAKDOWN AND BROKEN STRAP. (See p. 27.)

The nature and action of the slag is a very important factor in the manufacture of quiet steel. Slags are usually roughly classified by the melter according to the physical appearance. First is the dry, heavy slag, occurring when there is very little silica present. This is a dangerous slag if not carefully worked. The burning of many furnaces is due to this slag, as it reflects the heat to the roof. Another danger is the addition of too much fluorspar. The melter being deceived in the physical appearance of the slag, adds an excessive amount of spar. This results in a badly cut ladle and the burning off of the stopper rod. These disastrous results can be prevented by a gradual addition of spar until a wet slag is created, after which the heat may be worked down as usual. With natural gas the heat will foam for some time.

The second slag is wet, but lumpy. This is a good slag to work with. The lumps of limestone should be broken with a rod so that a rocky bottom may be avoided. In some cases the unbroken lumps will choke the tap hole while tapping out, and the slag being stopped, the steel is left uncovered until the tap hole can be freed of the lump of limestone, a large amount of heat being lost from the steel thereby. A lumpy slag can be avoided by charging small size limestone.

A third slag is the very watery variety, usually occurring when heats melt high. This is due to the presence of an excessive amount of silica. This slag should have burned dolomite or raw limestone added until a thick slag is made.

If a heat having a thin slag is tapped, the slag will mix with the steel and a wild steel will be the result. The ladle and stopper rod will be badly scorified and usually some tons of steel will be lost in the pit due to a burned-off stopper rod.

The ideal slag is heavy and wet with no large lumps. This slag makes an easy heat to work and gives a steel low in phosphorus and sulphur. It requires but a small amount of fluorspar to put this slag in shape for the ladle. A heavy slag of this nature will not mix with the steel and will generally stay in the furnace until the steel is nearly all in the ladle. It also has the good quality of cutting neither the

* Paper presented at the Cleveland meeting of the American Institute of Mining Engineers

stopper rod nor the ladle brick. The only objection is that it causes a dirty bottom, and unless a washout is made after each heat the bottom will rise to the sill plate level in every few heats. This result shows very poor practice, and no time is ultimately gained by charging without the usual washout. If a washout of 20 to 30 minutes is made after each heat the furnace will work fast for a much longer time. Also, the holes that occur in a high bottom will be largely avoided if the bottom is kept low and clean.

The tap hole should be kept large and low. The quicker the steel gets into the ladle the more heat is retained. The shorter the spout, the better it is for the same reason. Also a tap hole, if large, will not clog up easily if rabbling has to be done. In shutting up the tap hole, magnesite is best as it does not burn together, thus making a hard tap. Magnesite does not boil out as is the danger when a tap hole is shut with green dolomite. Burned dolomite is safely used for the above purpose.

These facts are probably known to most melters, but unless vigilance is constant one factor is apt to be overlooked. For example, the bottom may be low, tap hole all right, but the spout not being made up smooth at the end causes the stream to spray over the ladle, thus losing much heat and causing a skull and some misrun castings. These could have been avoided if the spout had been made carefully.

The addition of alloys may be made in the bath or ladle. By putting the alloys in the bath, much heat is saved. This is a valuable method where a furnace is working cold or a heat has melted low and there is difficulty in getting the heat hot. The advantage is that the additions are made while the flame is still on the bath and the loss of the heat in the bath caused by dissolving the alloys can be regained. The objections are: First, that a larger amount of each alloy must be added, as about 15 to 30 per cent. goes into the slag this way. Second, that the silicon reacting will throw back the phosphorus into the steel.

The second method of putting the additions into the steel as it goes into the ladle, is, in the author's opinion, the best. A uniform distribution of alloys is attained by shovelling the alloys in gradually. If the alloys are added in the ladle and they are first raised to a red heat, the steel will be helped greatly. This is especially true in winter.

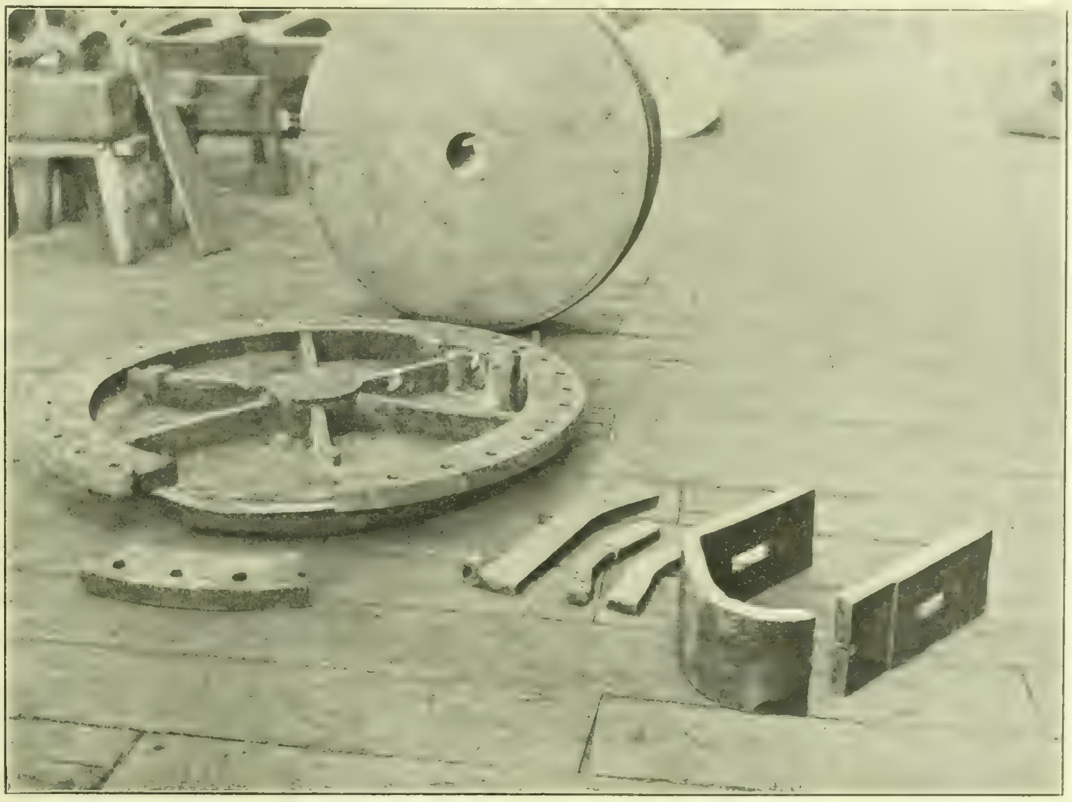
After the heat has melted and the limestone boiled, the heat will be benefitted by allowing it to soak for 15 to 30 minutes. This will allow any slag to rise and also much of the gases. Ore may then be fed, if necessary, or if the heat is ready, it remains only to get the steel hot.

Sometimes heats will melt low, and if one is hampered with small ladles or if there is no heavy work to pour it in, it is best to get the heat ready by using manganese. This will not add much metal to the bath and it is a good substitute for pig iron. Where there are large ladles the writer recommends working the heats with both pig iron and manganese. Very little, if any, ferro-silicon should be used instead of manganese, as the silicon mixes with the slag and cuts the stopper rod off when the heat is being poured. Hot metal is preferable to cold additions, as the bath is not then chilled by the addition.

The great danger in working stickers is, as usual, the working of the slag. The slag often looks thick and heavy, due to a cold bath. The mistake is made constantly of adding too much fluorspar. The result is that when the bath begins to pick up heat, the slag turns to water. If the heat is tapped with the slag in this condition and it takes more than 30 minutes to pour, the steel remaining in the ladle will be lost, as the stopper rod will be burnt off and the ladle badly cut. On the other hand, if the slag is watery and the attempt is made to thicken it, much heat will be lost and more time consumed before it will be ready to tap. This suggests the rule, "add fluorspar sparingly" and expensive mistakes will be avoided.

If the slag comes too quickly and the additions must be made in the first part of the heat, an even distribution can be obtained by rabbling the heat. If some of the additions are lost in the slag or not enough have been put in for the heat, which shows signs of wildness, a simple scheme consists of taking a number of sticks of aluminium and bending a tapping rod around them. The aluminium is then thrust to the bottom of the ladle, stirred around, and the bath rabbled afterward if necessary. There is hardly a heat that cannot be made absolutely quiet by this means. But it is a curative treatment, and a good preventive is always better.

The time consumed in pouring is a factor in determining the size of the heat. Good practice demands that a heat of steel should be poured in less than 60 minutes, the faster the better. To take longer than that length of time results in a reaction between the steel and slag. This reaction causes: (1) Loss of silicon and a gain in phosphorus and sulphur in the steel. (2) Steel shows wildness. (3) Skulling of ladle. (4) Misrun castings. (5) High ladle cost due to cutting of the brick by the slag. (6) The stopper rod becomes too hot and bending causes the loss of the remaining steel.



STEAM ENGINE BREAKDOWN. VIEW SHOWING THE CRACKED PISTON, BROKEN L.P. COVER AND BROKEN CONNECTING-ROD STRAP. (See p. 27.)

Again, the higher temperature required to pour steel from one to two hours causes a great gain in occluded gases and necessitates an increase of about 30 per cent. of ferro-silicon to make it as quiet as when a lower temperature is used.

The use of spar seems also to make the steel less responsive to the quieting action of silicon as the fluorine seems to be absorbed by the steel. The writer has noticed, when pouring a test, that after much spar has been used, the steel gives off a smoky gas of the same appearance as when fluorspar is added to the bath. If this is true, the action of fluorspar cannot be beneficial to the steel when added in large quantities.

Fatal Explosion on a French Battle-ship.—Through the bursting of a condenser on board the French battleship "Massena" at Toulon on Monday last eight men were killed and a number of others injured.

DEVELOPMENTS IN MACHINE TOOL DESIGN.

DURING the past ten years considerable changes have taken place in machine tool design, due mainly to the introduction of high-speed cutting tools. An interesting review of the progress made during this period is contained in the report of the Sub-committee on Machine Shop Practice appointed by the American Society of Mechanical Engineers, which was presented at a recent meeting of the society, and of which the following is an abstract.

While the increased capacity of machines which followed in the wake of the application of high-speed steel was directly instrumental in bringing about such increases in the weight of machines, the result has been beneficial, not only in increased production but in accuracy of product, because of greater rigidity and consequent better preservation of alignment. Progress has also been made in the methods of erecting machinery. With large size machines the foundation plays a most important part in the accuracy of the work produced. For instance, the provision of a massive, well-built foundation for large planing machines is imperative. When not provided, the weight of the machine and work must inevitably cause settling and springing out of shape. Every mechanic knows that such a disturbance of the foundation affects the alignment, which means that the work produced on the machine will be inaccurate. The elimination of defective action due to want of support and the increased mass and rigidity have in the case of planing machines resulted in the production of plane surfaces closely approaching theoretical planes when the work itself affords the necessary rigidity and uniformity of section. Hence, hand scraping to perfect alignment is not so necessary as it was a few years ago, and it may be said that on some classes of work scraping is now largely more of an ornamental than a corrective process. On high-grade machines, however, scraping or grinding probably will continue to be necessary to correct inaccuracies of surface and alignment.

The subject of electric motor drives was given much prominence in discussions of machine shop practice a few years ago, the bias being generally in favour of individual motor drive. While subsequent experience has shown that the direct-connected electric motor has certain limitations and disadvantages for some classes of work, it has also shown that the same results and efficiency cannot be obtained with the group system of driving modern designs of machine tools. The investment in motors is less with the group system, but the flexibility of the independent drive is lost. When a machine driven by an independent motor is properly equipped for easy handling increase of production over that of the same machine in a group system is practically ensured. One machine tool builder has found it a good rule to apply independent motors wherever the power requirement is 5 h.p. or more. Hardened steel gears in the driving train reduce gear troubles to a minimum. When the character of work is constantly changing and new groupings of machines are required from time to time, the individual drive is a great advantage.

Progress has been made in the development of automatic and semi-automatic machines for the production of duplicate parts from bar stock, iron and brass castings. Many special fixtures have been designed for automatic screw machines, which have widened their scope to include a great variety of small parts on which a number of operations must be performed before cutting off from the bar, such as small spiral gears, capstan screws, &c. The cost of production is so greatly reduced that these machines are generally applied where the quantity of work to be produced warrants the cost of installation and tool maintenance.

The turning and planing tools in many shops are now ground to standard shapes in the tool room on special tool grinding machines. This method not only saves the time of the machine tool operator, but ensures the grinding of all tools to the correct form, and it also saves what is of greater value—the loss of the productive time of the machine tool. The stock of tools required for a shop is also much smaller.

The important questions of speed and feed in connection with machining operations have, during recent years, been carefully studied by many superintendents and foremen who formerly relied entirely on the judgment of the workmen, which was sometimes good and sometimes bad. Speeds and feeds are fixed in the planning department and are based on the power of the machine and character of the metal.

More thought is now given to the selection of machine tools for various classes of work. A few years ago many shop foremen used a certain type of machine for a given class of work, because that type had always been used for that purpose. It seems that there is much less conservatism to-day and precedent does not count for as much as it did a few years ago. The tendency is to design the machine for the work instead of adapting the work to the machine equipment.

Machine parts are now carefully inspected in many shops by an independent inspection department, whereas formerly the only check on the accuracy of machined work was in the erecting department—if everything could be assembled, the work was considered satisfactory. The more exacting requirements of recent years, however, made necessary the general adoption of a rigorous system of inspection. Thorough inspection and testing are necessary features of interchangeable manufacturing methods; tools and systems have become highly specialised. Another improvement in shop practice worthy of mention is the more generous use of cooling mediums on cutting tools, and the provision of distribution systems from a central reservoir.

The up-to-date foreman or superintendent has come to realise that the efficiency of his shop depends largely on the amount of attention given to the little things. The furnishing of proper clamps and bolts to machine tool operators is a case in point. Poor bolts and warped clamps around a machine often double the time required for setting up work. At the present, most shops are equipped with proper clamping facilities and, in many cases, clamps of the right shape and bolts of the right length are furnished for each particular job, along with the other tools, such as cutters, reamers, &c.

More attention is given to the relative location of tools in the shop in order that all machining operations can be performed with no unnecessary handling of the work, the aim being to finish parts by advancing them from one tool to another in a direct line without any see-sawing or useless movements. Shops are constructed so that the light will be properly diffused, which makes it easier for the machinist to do accurate work and reduces the amount of spoiled work. The physical comfort of the workmen is also receiving more and more attention.

High-speed steel has been substituted for carbon steel in the manufacture of twist and flat twist drills with marked improvement in capacity. The speed of drilling has been increased two or three times, if not more. The drilling machine, the most common machine tool, has been re-designed to meet the new requirements, and so rapid are some of the most highly developed machines on the market that holes can be drilled in boiler-plate quicker than they can be punched. Multiple drilling machines with 2 to 50 or more drills in operation simultaneously have been developed. Inverted drilling machines with which the capacity of drills is increased largely because of the rapid clearing of chips from the holes are being used with satisfaction, also multiple drilling machines working in several planes simultaneously, making feasible the drilling and reaming of all holes in machine parts such as automobile cylinders at one operation. Another development is the rotary table semi-automatic drilling machines which relieve the operator of lifting and lowering the spindle and engaging and disengaging the feed.

A minor improvement of machine shop equipment which has increased the productive capacity of single-spindle drilling machines is the so-called roller grip drill chuck which enables the operator to insert and remove drills, reamers, counterbores, and other tools without stopping the spindle. These chucks are useful for certain kinds of work requiring drilling, reaming, and counterboring operations. In the same connection, mention should be made of tapping attachments, stud setting chucks, drill speeders, and similar attachments which improve the working range of drilling machines.

The need of the old style reversing countershaft has been eliminated from drilling machines by automatically reversing tapping attachments, automatically opening stud-setters, and many screw-threading operations are now performed on drill presses with special forms of automatically opening dies, at a

great saving over the former method of chucking the work on a turret lathe.

The improvements in lathes have been chiefly in matters of strength, power, and details of construction. Spindles are made larger and are supported in longer bearings, improvements have been made in carriages, tailstocks, tool rests, apron mechanism, stops, ways, spindle noses, gear boxes, change gear and feed mechanisms, &c. Three-stop cone pulleys and double back gear headstocks have been widely adopted for high-power rapid reduction lathes, this construction providing a wide range of speeds with simple and efficient mechanism. Quick change-gear mechanisms which enable the selection of gear combinations for screw thread cutting to be made practically instantaneous have been generally provided by lathe builders.

A remarkable increase of efficiency has been made in locomotive driving wheel and car wheel lathes. Ten years ago, turning the tyres of two pairs of drivers was a good day's work, and most railway shops did much less. High-speed steel has worked perhaps one of its greatest triumphs in this field. Tyre turning lathes have been developed to equal the capacity of the best steels and the productive capacity has been increased to eight or ten pairs of drivers a day. The increase of capacity of steel tyre car wheel lathes is even more marked, having been raised from five or six pairs to 18 or 20 pairs a day.

A weak feature of planers and a serious limitation to the power of large planers is the common shifting belt reversing mechanism. On small planers even the shifting belts are objectionable because of slipping and the characteristic squeaking noises, but on large planers their fault is of more serious nature. Wide belts necessary to transmit the required power at practical speeds cannot be shifted from the tight to the loose pulleys and vice versâ quickly. Clutches of various designs are used with varying degrees of success. The reversing electric motor direct connected to the planer drive has been developed to the point that makes its success assured. Probably this change of drive is the most marked improvement in planers made in recent years. Many details have been improved and the greater strength and rigidity of the modern planer coupled with excellent workmanship ensures accurate work.

A change in the machines for producing plane surfaces has been going on gradually but surely. Planers, shapers, and slotting machines are being displaced by various types of milling machines in manufacturing plants. As plants change from a building to a manufacturing basis the superiority of the milling machine as a manufacturing machine gives it the preference. The development of coarse-pitch teeth milling cutters and of face-milling machines are two of the marked improvements. Single-pulley drive with which the maximum power capacity of a given width belt can be transmitted to the machine irrespective of the work spindle speed, and geared speed boxes giving a wide range of positive speeds are other important changes in design. The vertical spindle milling machine has been developed to a high plane of efficiency, especially for small work. Rotary table machines with quick action clamping devices revolving continually while the operator places the work in position and removes the finished parts, are coming into extensive use.

The boring mill has taken a commanding place as a machine tool for both light and heavy work. When equipped with turret heads and a proper complement of tools its productive capacity has been made second to none. Convenience of operation, economy of floor space, compactness of design, adaptability to use of lubricants on cutting tools, are some of the advantages of this machine which have been emphasized in the new designs brought out in recent years. The horizontal boring machine of the bed and carriage type which has been developed practically within the past 10 years partakes of the characteristics of the lathe, milling machine and boring mill, and in the improved designs is superior to any one for certain classes of work. One of many uses to which it is devoted is that of boring jigs and fixtures for interchangeable production. But not only is it useful for jig making, but it is peculiarly well suited for manufacturing machine parts interchangeably without the use of jigs. This important fact enables machine tools and similar high-grade machines to be economically produced on the interchangeable plan during the very active period of developing the design.

Magnetism for holding steel and iron parts for grinding, planing and turning operations has been made useful, especially for thin parts that are easily sprung out of shape by ordinary clamping means. Magnetic grinding, planing, and lathe chucks have come into common use in plants having up-to-date equipment.

The surface grinder, especially the vertical spindle type, has made great strides in the last few years. The improvements in cylindrical grinding methods are also worthy of mention, especially the use of the heavy duty grinder for removing stock formerly removed by a second or finishing cut in a lathe. Grinding stock from the rough as in the finishing of drop forged crank shafts is also a good example of modern practice. The stage has been reached in cylindrical grinding practice which places the cylindrical grinding machine on a co-ordinate basis with the lathe as a tool for finishing cylindrical work.

A feature of cylindrical grinding machines which has greatly increased productive capacity in multiple diameter work is the stop bar or semi-automatic measuring attachment which enables shouldered shafts, &c., to be duplicated without measurement. Machines for internal grinding of non-revolving work with planetary spindles provides for the economical and accurate sizing of engine cylinders and other parts difficult to rotate. Vertical grinding machines and rotary work tables utilising magnetic chucks or other quick action clamping means for quickly securing and releasing the parts to be ground have come into extensive use for high-grade interchangeable manufacturing. The development of the disc grinder from a mere smoothing machine to a place as a powerful machine tool of great capacity for finishing plain and curved castings from the rough is one of the most interesting phases of modern practice.

The development of jigs and fixtures for interchangeable manufacturing has been remarkable. The expansion of automobile manufacture has been enormous, and most of the leading concerns employ jigs and fixtures exclusively, thus ensuring interchangeability, low production cost and systematic production. Many improvements have been made in the way of clamping devices, standarisation of bushings, handles, levers, frames, &c., too numerous to mention specifically. Tool making has been developed on manufacturing lines, and in fact several concerns specialise on the making of tools, jigs, fixtures, punches, and dies, and produce them exclusively for manufacturing plants.

The demands of automobile users for quiet running gears have imposed on gear makers conditions very difficult to meet. The limits of error in shape and spacing of teeth have been greatly reduced and coupled with the necessity of making highly accurate gears, often has been that of producing them from tough alloy steels heat treated after cutting the teeth. Hardened and case-hardened gears are also demanded with minimum limits of error. The planing process has been generally substituted for milling in the manufacture of high grade bevel gears, thus producing theoretically correct tooth shapes instead of the approximation possible only by the former milling cutter process.

Gear hobbing machines have been widely adopted for cutting spur and spiral gears, because of the greatly increased capacity and simplicity of operation. Machines and methods of cutting the teeth of integral herringbone gears cheaply have been developed, thus making this form of gear available for machinery generally in which it has not been commonly used because of high cost of the two-part type. The demand of automobile users for noiseless gears has led to grinding the teeth of gears after hardening to correct form and form grinding generally, including splined shafts for automobile change gear shafts and similar parts. Progress has been effected in the making of gears by the hot rolling process, producing them thus with a minimum waste of material and of exceptional physical characteristics.

The design and manufacture of small tools have been improved principally in details. There has been a tendency to decrease the number of teeth of milling cutters, making possible heavier roughing cuts with proportionately less expenditure of power. While the extreme coarse spacing of the teeth advocated by some leading engineers has not been gene-

rally adopted, all manufacturers of milling cutters have to some extent modified the tooth spacing of their cutters. Several special milling cutters with inserted teeth have also been proposed, and to some extent adopted. The tendency has been towards the design of easily adjusted removable blade type reamers, and several satisfactory designs have been brought out. The flat twisted high-speed steel drill has been commercially developed and several modifications of it have been placed on the market. The main progress in tap making, perhaps, has been towards a more satisfactory shape of the flute, and several tap makers have made experiments in this direction.

In general there has been an attempt to design inserted cutter tools to a greater extent than formerly. This activity has been prompted largely by the high price of high-speed steel which has made it necessary to make the cutters only from this material, while the body and shanks of the tools are made of machine steel. Many experiments have been made to find the steels best adapted for a given service and the best heat treatment for the selected steels. Improvements have been made in the tangs of twist and flat drills adding strength sufficient to enable them to stand up to the requirements of high-speed drilling and drilling machines.

During the past 10 years the micrometer has become a measuring tool of general use. Many shops supply them from the tool rooms on the workman's checks. As the result of the general use of the micrometer, $\frac{1}{1000}$in. has become the unit of measurement for fixing limits, and a limit of 0·00025in. is not uncommon in grinding operations. Not only is there a great advantage in the matter of accuracy in the use of micrometers over the old style of calipers set to a scale, but there is a considerable saving in time through their use, both in the matter of setting to size and in eliminating the element of uncertainty, permitting the workman to proceed with his work with greater confidence.

The changes in brass working are principally in the development of automatic and semi-automatic machines for machining standard parts made in large quantities. Some of the machines have effected great reductions in cost, cutting in some cases the labour cost to one-fifth or less of that before the change was made. Carbon steel tools still have the call in some plants in preference to high-speed steel tools; carbon steel holds a keener edge and is generally more satisfactory for working the brass used in the manufacture of globe valves, cocks, &c. It is claimed, however, that much of the difficulty experienced in using high-speed steel on work of this character is due to improper heat treatment of the high-speed steel, and this contention seems to be borne out in practice, as certain shops doing brass work of this character are using high-speed steel exclusively.

Chucks operated by compressed air have made a great improvement in the operating efficiency of brass lathes. The work can be chucked and removed without stopping the work spindle, thus saving the time and strength of the operator. The development of the air chuck has taken place chiefly within the past few years, and it is one of the principal improvements made in hand-operated turret lathes.

Press working machines, punches, dies, and other tools have developed to an extent not generally realised by engineers in lines not effected. Here again the development of highly specialised methods of manufacturing automobiles has had a marked influence. Crank presses of 1,000 tons capacity are in use. Pressed metal forms of large size are a commonplace. But not only has the development been remarkable in point of size, but also in detail of manipulation. Parts requiring several operations, for example, are turned out by multiple plunger presses, one finished piece being formed at every stroke.

An interesting feature of press work is that shapes are produced impossible of duplication by any other known process. In this respect press work differs from most other machining processes; it is possible to duplicate, for example, lathe or planer work by hand tools, but not so many drawing and forming operations in daily use. A branch of press work little known is the extrusion of shells, tubes, collapsible tubes, &c., of copper, brass, and alloys. Extrusion of bars in many shapes used in manufacturing locks, small machines, &c., has become a large industry which has been largely developed in recent years. The possibilities of extrusion are practically unlimited, and this process in common with other metal working methods extensively used has an important effect on the practice of shops using the shapes in their products.

Finishing processes are important in giving attractiveness to manufactured goods. Hand methods are slow and costly and the natural tendency is to use automatic mechanical methods for finishing as well as for making One process of considerable interest because of its simplicity and effectiveness is the steel ball burnishing method, consisting essentially of a tumbling barrel partly filled with the articles to be finished and a mass of hardened steel balls of various sizes.

The development of oxy-acetylene and oxy-hydrogen welding and cutting torches has given the industrial world truly remarkable tools for building up or cutting apart. The welding of sheet metals is accomplished with speed and evenness hardly possible by any other process, and the cutting of steel or wrought iron is done close to the line and with such rapidity as to equal or exceed the performance of any machine tool adapted for the same work. Recent improvements make possible the cutting of all manner of shapes from steel plates up to 6in. thickness so close to the outline of the pattern that a light finishing cut suffices to transform the piece into a finished die.

Time and space will not permit going much more into detail, and the following are enumerated without elaboration: Introduction of ball bearings in the construction of machine tools, effecting a saving of power, increasing the efficiency of operation and capacity through reduction of bearing widths; development of cam grinding machinery and attachments making possible the rapid and economical production of camshafts having cams integral with the shaft; development of the dynamic balancing and the general recognition of the need of dynamic balancing for high-speed revolving parts; artificial production of highly efficient abrasives or cutting particles for grinding wheels and improvements in grinding wheel manufacture; development of improved lubricating systems for machine-tool bearings; development of machine tools to their utmost capacity by providing means for working the tools all the time, employing extra men to prepare work and also by tooling the machines to bring them up to their highest productive capacity; development of spline milling machines for cutting keyways, key slots, drift holes, cam grooves, recesses, &c.; finishing square, hexagon and other shape holes by the broaching process, ensuring interchangeability and rapid production at low cost.

Corrosion of Monel Metal.—According to experiments made at the laboratory of the Board of Water Supply, New York City, Monel metal possesses about the same resistance to corrosive action as the better-known bronzes, while in these tests it had the additional advantage that it presented the least change in appearance as a result of the corrosive action. Specimens of several bronzes, Monel metal, and steel were weighed and embedded in rich earth, which was kept wet for 6 months by periodical additions of very dilute solutions of corrosive salts. At the end of the test period, all of the specimens were taken out, scrubbed, dried, and weighed to ascertain the comparative loss from corrosion. The results in percentage of loss were as follows: Phosphor-bronze, 0·09; Tobin bronze, 0·11; Monel metal, 0·12; Parsons manganese-bronze, 0·12; Muntz metal, 0·33; and steel, 1·04.

American Society of Mechanical Engineers to Visit Germany.—Arrangements have been made for the American Society of Mechanical Engineers to hold a joint meeting with the Verein Deutscher-Ingenieure in Germany during the coming summer. The American visitors will arrive in Hamburg on June 21st, and after inspecting the shipyards will proceed to Leipzig. There, at the formal opening of the meeting, two addresses will be given, one by a representative of the German and the other by a representative of the American Society, on general subjects, such as the history of engineering, the relations of capital and labour, and the effect of technical education on industry. On the following day technical papers will be discussed. The party will then start on a tour lasting about a fortnight through industrial Germany, the places to be visited including Dresden, Berlin, Düsseldorf, Cologne, Frankfurt a/M., Nürnberg, and Munich. It is expected that the Krupp works at Essen will be opened for their inspection.

USE OF COMPRESSED AIR IN FOUNDRY PRACTICE.*

BY ARTHUR F. MURRAY.

It is not the purpose of this paper to present a scientific treatise on compressed air, or a mass of figures as to costs of operation and resultant savings. These are so dependent on individual conditions that figures drawn from general statements would be of little value. I shall merely attempt to outline the uses to which compressed air is put by the wide-awake foundryman. It may be well to list the more important uses for compressed air in the foundry. They include: Air hoists; pneumatic elevators; pneumatic cupola charging machines; fuel oil systems; core carriage hauling devices; core sand preparation (pneumatic riddles); core-making machines; moulding machines; pneumatic rammers; pneumatic moulding sand sifters or riddles; blow guns; spraying devices; pneumatic chippers; sand blasts, high or low pressure; sand blast tumbling barrels.

The air elevator is used frequently in place of the hydraulic elevator for sand pits or other places where the hydraulic elevator would require the installation of long lines of large piping, expensive pump installations, and troubles from freezing. It is simple, cheap, and effective, although not to be recommended for the continuous service of the cupola stage. Where the lift is long, indirect air elevators, similar to the indirect hydraulic elevators used in office buildings, are frequently employed.

A great many foundries use fuel oil for skin drying, melting furnaces, core ovens, &c. The air displacement system is a simple means of transporting this from the place of storage to the place of use. In this system air is not applied directly to the storage tanks, but alternately to two small pressure tanks which receive their supply of oil by gravity from the main storage tanks. Simple cross-over valves are used, and are changed over once or twice a day, usually by hand, but sometimes automatically.

The core-room is often a neglected part of an otherwise up-to-date plant. Therefore, opportunities for savings are usually good. If core costs can be sufficiently reduced, the entire moulding practice may be radically changed, coring taking the place of difficult pockets, loose part work, or multiple part flasks. Jolt machines for making cores are meeting with increasing favour. For success on core jolt machines, boxes must be substantially built or they will be knocked to pieces. But the cost of a well-built core box is little more than that of a poorly built one, and the use of core jolt machines will reduce most core costs 25 to 50 per cent.

One of the most remarkable changes in foundry practice during the past five years has been caused by the general adoption of the jarring machine, jolt-rammer, bumper, or bouncer, as it is variously termed by makers and users. No other single type of moulding machine is applicable to as wide a range of work, or requires as little special pattern and flask work.

One of the most essential requirements for the profitable operation of jarring machines is efficient crane service. Nothing will show up the crane service like the presence of a good-sized jarring machine on the moulding floor. Inefficient crane service in a hand-moulding foundry, of course, means idle time for the moulder, but he will usually not make much of a row about that. When the jarring machine comes in, the foreman and manager are watching it, and delays caused by the crane are quickly noted. In properly operating the jarring machine, moulds are set up on the floor, clamped, picked up by the crane, carried to the machine and rammed, picked up again and turned over, and then carried to the finishing floor by the crane. In connection with the jar-ramming machine in our foundry, I have found it profitable to install 5-ton independent high-speed auxiliary hoists on each of the two 60ft. travelling cranes, as well as in a 2-ton electric jib crane and an 8in. air hoist.

The jarring machine, though covering a wide range of work, is not a universal panacea for high costs and poor castings. For speciality work the plain hand squeezer with vibrator attachment is widely used. For this same class of work the ramming is sometimes done by hand or on a plain squeezer, and the pattern drawn by a sucker with vibrator attachment.

The subject of sand blasting is so broad that it can only be treated adequately in a separate paper. However, compressed air is used extensively for cleaning castings. For cleaning small castings that are not fragile the sand blast tumbling barrel renders excellent service. There are a number of machines built on the principle of a rotating barrel with one or both heads stationary. A nozzle or nozzles from a regular sand blast machine is inserted through openings in these heads. Most of these machines operate on the low-pressure system. Some return the sand to the machine by a suction system and some by gravity. They all operate inside of an outer case closed by sliding, swinging, or rolling door, and connected to an exhaust system.

An efficient sand blast or sand blast tumbler, either of the high or low pressure type, will remove sand and scale, and will leave castings better looking than either a plain rumbling machine or the emery brick, wire brush, and pickling tank. Castings have been cleaned and their cores cut out in less than an hour each with the sand blast that could not be cleaned by hand in two days. I know of one plant where a sand blast tumbling barrel replaced a pickling tank, with the result that shipments could be made at least one day earlier than before. The product required galvanising, and was sand blasted and put in the galvanising bath the day after it was cast, instead of losing a day in the pickling vat. The casting now being clean, the fins, &c., are chipped off with a pneumatic chipping hammer. One man chipping with a chipping hammer is as good as two or three with hand chisel and sledge, and the work looks better and smoother. A skilled chipper will quickly remove fins or bunches so that they appear scarcely to have existed.

A few words about the care and upkeep of pneumatic tools. Before attaching a tool, blow out the air line and squirt oil into the valve. Do not use an air hammer all day long without oiling it. If the hammer has not been used for some time, squirt a little kerosene or benzine into it, connect up the hose, operate the machine for a few strokes, then disconnect and squirt a light machine oil, or sewing-machine oil, into the hammer. Several of the large oil refiners now supply a special pneumatic tool oil, which should be used if possible. New hammers are always furnished with a gauze strainer. This should be kept in good condition, as rubber particles and rust from hose and pipes are liable to clog valve passages if allowed to get into hammers. It is a good plan to suspend the hammers over night in a bath of kerosene to clean them out and to prevent rusting from moisture in the air. They must then be lubricated before using, as the kerosene leaves them dry. There are a number of makes of automatic oilers on the market to be attached to the air line a few feet from the hammer. If none of these is used the hammer should be oiled several times a day. Chisels should be kept in shape, and in general the hammer should be treated as if it were a piece of machinery rather than a piece of scrap iron.

Piping should be as direct as possible, with no undrained pockets or loops where moisture can accumulate and where freezing can occur in cold weather. Separators should be installed at low points on the line. These may be either the ordinary type similar to steam separators or they may be air receivers. It is a good plan to locate a steel receiver of 25 cub. ft. to 50 cub. ft. capacity at points where there are large fluctuations in compressed air demands. This combines the action of separator and equaliser, although it will not sustain the service if the compressor shuts down. Fittings should be of the long-turn type and all shut-off valves of the gate type. All shut-off cocks on taps should be of heavy pattern and good quality. The piping should be installed with care to ensure a tight line, and should be well supported so that the joints cannot shake loose. A single $\frac{1}{8}$in. orifice will deliver 21·2 cub. ft. of free air per minute at 80lb. pressure. Hose should be heavy and preferably armoured. Quick-acting couplings should be supplied at both ends of the hose to prevent the reprehensible practice of twisting it before screwing it into a tool connection.

After-coolers and reheaters are usually unnecessary with foundry outfits, but where there is a plentiful supply of

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* Abstract of paper presented at the Buffalo meeting of the American Foundrymen's Association.

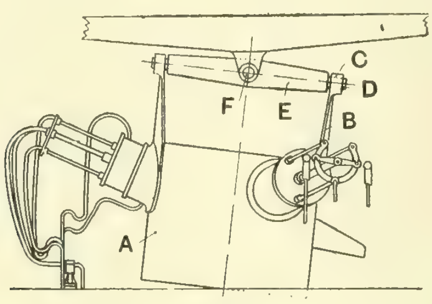
cooling water the use of a properly proportioned after-cooler will remove nearly all the moisture from the air before discharging the air into the pipe line.

The average jobbing foundry requires a compressor of 300 cub. ft. to 500 cub. ft. per minute displacement. Large foundries may use up to 1,500 cub. ft. or 2,500 cub. ft. Specialty foundries frequently require small machines of 50 cub. ft. to 100 cub. ft. displacement. In selecting a foundry compressor, price should not be considered so much as service. The foundry compressor should be as nearly dirt-proof and fool-proof as possible. Machines that would give perfect satisfaction when operated in connection with a power plant and in charge of skilled engineers frequently go to pieces when installed in a foundry where skilled mechanics are not available, and where dirt and dust abound. These remarks refer not so much to the large foundry which maintains a power plant either for itself or jointly with other departments of the works, as to the independent jobbing foundry which produces a large percentage of our total foundry product.

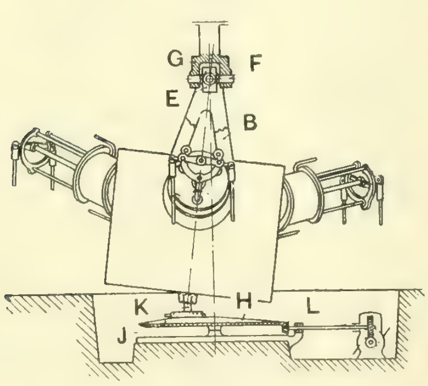
THE STASSANO ELECTRIC FURNACE.

In the original design of the Stassano electric furnace the suspension of the furnace chamber was effected by mounting the casing which surrounds the chamber, by means of a pair of pivots, on a ring which in turn was mounted on fixed supports through the agency of a second pair of pivots positioned at 90° with respect to the first-named pivots. This arrangement has, however, been attended with difficulties, and to obviate these Mr. Stassano, of 17, Via Bogino, Turin, Italy, has designed and patented the method of suspension illustrated, by means of which a simple oscillatory movement of the furnace chamber gives rise to a complete stirring of the molten mass contained in the chamber.

Referring to the illustrations, the casing A, which envelopes the furnace chamber, carries two fixed stirrups B, constituting at their upper parts supports C for the reception



No. 1.



No. 2.

Stassano Electric Furnace.

of the pivots D on the end of a cross member E having on its sides other pivots F situated at right angles to pivots D and mounted in bearings G which are carried by an upper cross member. The suspension device thus comprises a single bar provided with two pairs of pivots, one pair being at its ends and one pair on its sides. An oscillatory or turning movement may be communicated to the chamber by means of the gear wheel H, which carries a part J adjustably mounted and provided with a projection K that engages into a socket fixed to the bottom of the casing A. The wheel H is actuated by a pinion L driven by a suitable motor.

AXIOMS CONCERNING MANUFACTURING COSTS.*

BY HENRY R. TOWNE.

Three factors enter into the cost of each and every article of manufacture, viz., materials, labour, and expenses. These constitute a tripod, a three-legged stool, which cannot stand if one of these legs be omitted. They may, and do, vary in dimension, but all three are invariably present, and a "cost" which omits any one of them is incomplete and fallacious. The formula is

$$L + M + E = C$$

in which L represents labour, M materials, E expenses, and C cost. In this primary division the item "labour" includes all labour entering directly into the product, the item "material" all material entering directly into the product, and the item "expenses" (often called overhead charges, or simply overheads) all other labour, material, and expenditures of every kind whatsoever.

Axiom 1 Every cost includes three fundamental factors: labour, material, expenses.

In most cases, however, the expenses, or overheads, divide naturally into two groups: (*a*) Manufacturing expenses, those incident to the operation of the factory or mill; that is, those incurred in utilising productive labour and material, and in bringing the product up to the point where it is ready to be sold. (*b*) Commercial expenses, those incident to the commercial department of the business, including administration, salesmen, advertising, office expenses, &c.; that is, those incurred in distributing and selling the finished product. It is highly expedient that these two should be segregated, so that each may be studied separately.

Axiom 2 The expense factor should be split into two parts: manufacturing, commercial.

Letting the symbol Me represent the former, and the symbol Ce the latter,

$$L + M + Me + Ce = C$$

But a more convenient and indicative form of presenting these elementary facts, one which the writer has used for many years, is the following:—

L = productive labour.

M = productive material.

$\overline{PC}$ = *prime cost.*

Me = manufacturing expenses.

$\overline{SC}$ = *shop cost.*

Ce = commercial expenses.

$\overline{AC}$ = *actual cost.*

If preferred, the foregoing facts may be expressed by the following formulæ:—

$L + M = PC$ or *prime cost.*

$PC + Me = SC$ or *shop cost.*

$SC + Ce = AC$ or *actual cost.*

Axiom 3 A manufacturing cost has three phases: prime cost, shop cost, actual cost.

On the appreciation and intelligent use of these facts hang all the laws of good business and the profits, for no business can long be operated successfully without a correct knowledge of costs, nor can that be had without a clear grasp of fundamental principles. The competitor most to be feared, while he lasts, is one who does not know his costs, nor understand how to obtain them.

Axiom 4 Accurate cost information is vital to good management.

Simple as are these elementary principles, their correct application in each given case is difficult, and calls for great care and intelligence. To draw correctly the line between productive and non-productive labour and material, through each of the successive stages of a productive industry, requires the combined skill of the expert manufacturer and the expert industrial accountant; the former knowing accurately all the details of the manufacturing or productive processes,

* Paper read before the American Society of Mechanical Engineers.

and the latter knowing equally the proper methods of combining and using the recorded facts to yield the desired information. For example, what constitutes productive labour? In the case of a machinist operating a lathe, clearly it includes his wages while his lathe is turning out product and also while it is standing still during the time he is dressing the tool to do the work properly. But if the tool-dressing is done for him, as it is under good modern practice, how shall the time and wages of the tool-dresser be classified? So as to productive material, shall the tool, the file, the waste, the oil which are consumed or used up in making the product be classified as productive or as non-productive material? The answers to these questions depend on the surrounding facts in each case, and are as varied as the cases are infinite in number and variety. The writer is not attempting here to answer such questions, but merely to point out and emphasize underlying principles. This much is clear, that every individual item of expenditure, large and small, must ultimately classify under one of the three great heads above referred to, labour, materials, or expenses, and that profit, or loss, is the difference between actual cost and the net price realised.

Axiom 5 Accurate costs imply the correct classification of every expenditure.

The distribution of actual costs among these heads, or, preferably, into the four groups or divisions indicated above, varies widely in different industries and with different products. This is illustrated by the following table, relating to four distinct lines of actual product, in which the several elements have been reduced to terms of the actual cost of the product when finished and sold.

	Nos. 1	2	3	4
L = productive labour ...	28	17	29	19
M = productive material	38	33	25	37
PC = prime cost	66	50	54	56
Me = manufacturing expenses	24	20	28	22
SC = shop cost	90	70	82	78
Ce = commercial expenses	10	30	18	22
AC = actual cost	100	100	100	100
Total expenses (that is, $Me+Ce$) =	34	50	46	44

The figures in the above table illustrate the hopeless state of mind of manufacturers, some of whom still survive, who delude themselves by the belief that the sum of labour and materials (prime cost) represents the actual cost of the product, and that the difference between that and the selling price is profit. They show, on the contrary, that, in the four examples to which the figures relate, the prime cost constitutes only from one-half to two-thirds of the actual cost, and that the expenses, or overheads, incident to conducting the business and marketing the product, contribute from one-third to one-half of the total or actual cost. It seems probable that, if the facts concerning all manufacturing industries could be ascertained and averaged, the "three-legged stool" would be found to stand nearly level, its three legs being approximately of equal length, although differing widely in individual cases.

All cost accounting should aim to segregate charges wherever this can be done accurately. Thus the major part of the items constituting productive labour and material can and should be charged directly to their respective accounts, L and M.

Axiom 6 Every productive expenditure should be charged directly to its proper account.

All other items, however, which cannot be so segregated must be aggregated into one or several groups and their total apportioned among the proper accounts on some carefully determined but necessarily arbitrary basis.

Axiom 7 All non-productive expenditures should be properly grouped for final distribution.

Manufacturing expenses may be apportioned as a ratio or percentage of labour L, of material M, or of labour and material $L+M$. The usual bases are either L or $L+M$. The writer believes that in most cases the closest conformity to actual facts will be attained by distributing manufacturing expenses in the ratio of productive labour, hand and machine, because usually the volume of indirect expenses of works operation will be far more influenced by the pay-roll, that is, by the number and kinds of employés, than by the materials bill, that is, the amount paid for the material of production. Moreover, the former is relatively stable, while the latter fluctuates with market changes. Therefore it is advisable that Me should be a function of L, that manufacturing expenses should be apportioned as a percentage of productive labour, although in some cases they may properly be apportioned per machine, or per unit of floor space.

Axiom 8 The normal basis for distributing manufacturing expenses is productive labour.

Commercial expenses may also be apportioned as a percentage of L, of M, or of $L+M$, and frequently are, but more properly they should be apportioned on the basis of shop costs, $L+M+Me$. The reasons for this are conclusive. Production and selling are two separate and distinct processes. The former brings the product to the point where it is completed and ready for sale; the latter then takes it over and effects the sale. The expenses incurred in each process are for its use only, and have no natural relation to the needs and uses of the other. To illustrate this, take the case of a manufacturer of cotton cloth who sells his entire product through a commission house or broker. Clearly his whole commercial expense account is covered by the commission he pays to his selling agent, and this bears a definite ratio to his shop cost, that is, to the cost of his product ready for sale. Now, take the case of another manufacturer of cotton cloth, who maintains his own selling organisation and through it distributes his product. Clearly his commercial expenses offset the commission paid by his competitor, and equally bear a definite ratio to his shop cost. Both are most accurately stated and apportioned as a percentage of the shop cost, the cost of the product ready for sale. Therefore commercial expenses Ce should be distributed as a percentage of shop cost, $L+M+Me$.

Axiom 9 The normal basis for distributing commercial expenses is shop cost.

When the product is simple and homogeneous, for example, such as pig iron or cotton cloth, one account may suffice for all manufacturing expenses and one other for all commercial expenses, but when it is diverse or complex each of these should be sub-divided into one for each department or for each distinct class of product. In effect such a business is an aggregate of several businesses, some of which may yield better results than others, or may fluctuate more widely, and a proper accounting system should show the results of each sub-division or department separately, as well as the combined result of all. Hence arises in many cases great complexity in cost accounting, and corresponding need and opportunity for the skilled industrial accountant.

Axiom 10 An accounting system should show results both by departments and by totals.

In some cases the entire product consists of a single staple article, or group of articles, for which there is a constant demand and, at some price, a sure sale, such as pig iron, window glass, cotton cloth, &c. In other cases the product must conform to the specifications of the customer, and therefore cannot be made up in advance of orders, as in shipbuilding, carbuilding, and the construction of buildings. The former is commonly designated as a stock product, and the latter as contract work. The difference between these may be expressed as follows, viz.: A stock product is one which is made first and sold afterwards; a contract product is one which is sold first and made afterwards. Cost accounting is usually more complex and difficult in the case of contract work than in that of a staple or stock product.

Axiom 11 A contract product may require a more complex accounting system than a stock product for the accurate determination of costs.

The expenses of general administration overlap the manufacturing and the commercial divisions of an industrial business. Many items can and should be definitely charged to one or the other. Others may arbitrarily be apportioned between them; as, for example, the salary of an official who devotes, say, 70 per cent. of his time to one and 30 per cent. to the other. All others must be aggregated into groups for distribution by the methods adopted, as above, for distributing such expenses; as, for example, by percentages of productive labour or of shop costs. Expenditures of this

kind are infinite in size, kind, and number, and call for great skill and good judgment in their classification, which should be determined in advance by a clearly defined code, not left for haphazard decision by subordinates. Such a code, based on intimate knowledge of the business, on a clear perception of the information of the code is designed to yield, and on sound accounting principles, is an indispensable prerequisite to the accurate determination of costs, and equally to the intelligent conduct of any manufacturing business.

Axiom 12 An accounting system should be embodied in a code of instructions, for the guidance of those responsible for its operation.

For best convenience a code should provide symbols to represent the various accounts and their many combinations. For this purpose the writer for many years has used a system of letters and numbers which possesses great convenience. Letters are used to designate important departments and accounts, the significance of each letter depending on its place, as in decimal notation, in the symbol. Thus, the first letter may indicate a department, the second a sub-division of it, and the third a room or smaller unit. Stated numbers are used to indicate accounts relating to expenses of the various kinds or groups. Such a symbol is shown by the following example, viz.:—

BAC 10

in which *B* represents the department, or the class of product, against which the item is to be charged; *A* the shop in which the work is done; *C* the job, or machine, by which it is done; and 10 the kind of expense to which the charge relates, such as repairs of the machine, foreman's wages, &c. These symbols and an explanation of their meaning and use are printed in a small book of pocket size, copies of which are furnished to all concerned. In this way a correct classification of every charge is made at the time of original entry, after which tabulation and aggregation of original charges follow automatically in accordance with the predetermined plan.

Axiom 13 Symbols are better than titles for recording charges in an extensive accounting system.

In any business certain expenses or losses occur from time to time which are unusual or abnormal. These may be termed "extraordinary expenses," and require special consideration. As examples of these may be cited a serious loss by fire, a curtailment of product by a strike, an abnormal loss through bad debts, an increase or decrease in value of land, &c. The loss, or profit, thus arising must, of course, be covered into the treasury, but this may better be done through a debit or credit to the surplus account than through a charge to the profit and loss account of the current year, for the latter plan would distort the statistical record of the year by including in it items not common to normal years. The best plan is to charge to the account of each year only the items which are normal, and to charge those which are abnormal to the surplus account. The proper purpose of the annual account is twofold, (*a*) to show the results of the year's operations, and (*b*) to contrast these results with those of preceding and succeeding years. On the other hand, all extraordinary gains or losses must be accounted for, and this may best be done through the surplus account. In this way both purposes are accomplished.

Axiom 14 Extraordinary gains or losses, in order not to distort the statistical value of the annual profit and loss record, should be covered into the surplus account between the closing of the books for the old year and the opening of the books for the new year.

Interest on borrowed capital is a distribution of profits, not an expense, although often erroneously treated as the latter. To illustrate this, suppose the case of two manufacturers, *A* and *B*, each having £40,000 invested in his business and each realising 10 per cent., or £4,000, net profit available for dividends on a year's business, all of *A*'s capital being contributed in cash, while *B* has only £20,000 of cash capital, and another £20,000 of borrowed capital, on which he pays 5 per cent. interest. At the close of the year *A* is in a position to pay £4,000 in dividends to his stockholders, a 10 per cent. return on their investment, but *B*, after paying £1,000 as interest, is in a position to pay £3,000 in dividends to his stockholders, a 15 per cent. return on their investment. Evidently the actual profits from the operations of the year are the same in each case, only the ownership of the capital invested and the distribution of the profits being different. The accounting system should show the actual profit realised, regardless of its distribution to the owners of the capital invested in the business. On the other hand, it is expedient that interest on temporary loans, and on time purchases if availed of, rebates and discounts of customers' notes, should be treated as current expenses, normal to the conduct of the business. In like manner discounts earned by cash payments should be treated collectively as part of the current earnings of the year, or else be covered into the net costs of purchases.

Axiom 15 Interest on borrowed capital should not be treated as an operating expense, but should be charged direct to the profit and loss account of the year.

Interest on all capital invested in a business may or may not be deducted before stating the final profits of the year. Here no principle is involved, but merely convention or individual preference. Usage, however, has practically determined that it shall not be deducted; that the final, or net, profit should indicate the return on capital, the amount which capital has earned. Stated thus, it can readily be compared with what the same capital would earn if invested otherwise; as, for example, in Government or railroad bonds, in mortgages, &c. If interest is deducted at all, as is done, for example, under some profit-sharing plans before allotting anything to the beneficiaries of the plan, it should be computed on the total capital invested in the business, including therein the surplus account; that is, surplus profits of previous years retained in the business and invested in plant or merchandise.

Axiom 16 Final profits properly signify the amount earned by the capital invested. If interest on capital is deducted this fact should be stated, and interest should be computed on the total capital employed.

Where a business is divided into several or many departments it is very desirable that the accounting system should show the profits or earnings of each of them separately, and this is usually feasible, except as to annual depreciations and as to interest charges. In some cases either or both of these items can accurately be distributed among the several departments, and if so they should be so treated. Where they cannot be so distributed they should be deducted in a lump from the sum of departmental profits, and in this case it becomes convenient to adopt terms to designate clearly the profit account at its various stages. For this purpose the writer has found the following terms satisfactory:—

Gross profits: the aggregate profits of all departments, prior to deducting depreciations and interest.

Net earnings: the gross profits after deducting depreciations.

Net profits: the net earnings after deducting interest on borrowed capital.

In comparing the results realised in two or more comparable concerns or businesses, it is essential to contrast profits at the same stage in each case, and to employ terms which are mutually understood as to their precise meanings. No standard as to these terms has yet been established. The proper basis of comparison usually is that indicated above by the term net earnings, which eliminates the variations due to the employment or non-employment of borrowed capital.

Axiom 17 Terms used to designate profits should indicate clearly the stage of profits to which they refer, and should be mutually understood.

Inventory valuations are an important factor in determining profits. Usually an actual inventory is taken only once a year. The merchandise inventory includes raw materials, stock in process, finished goods, and general supplies. A standard basis of valuation for each of these groups should be adopted and maintained from year to year. Raw materials, such as pig iron, raw sugar, baled cotton, ingot

copper, &c., are often subject to wide fluctuations in market values or costs, and the question thus arises as to the proper inventory valuation of them, whether at cost, at market value at date of inventory, or on some arbitrary basis. If the effect of such fluctuations is negligible, that is, is small in ratio to the annual total of the account, either of the first two methods above stated may be used. If the fluctuations are large, however, either in range or in their effect on the annual total, that is, if they materially influence the profit and loss account of the year, some arbitrary plan of accounting for them should be adopted. In devising this, the twofold purpose of the annual account, the operative and the statistical, should be kept in view. If the effect of the fluctuations is moderate in its ratio to the annual account a sound method consists in taking the mean, either of market prices or of actual purchase prices for, say, three or five years, as the basis for inventory valuations, and also for use in the compilation of costs, thus conforming to the average trend of market values, but avoiding frequent and temporary changes. If, however, the effect of these fluctuations is serious or vital in determining the results of the business, a new factor is brought into the accounting problem, namely, that of trading or speculating on the market. In the case of a sugar refinery or a cotton mill, for example, large profits or losses may result from market changes in the price of raw sugar or of baled cotton, or from the operations of the purchasing department. Obviously, such gains and losses are totally unrelated to the economy and efficiency of the productive department, and to include them in its accounting might so distort it as to destroy its usefulness and its statistical value. In such cases a separate trading account should be established, through which to ascertain the profit or loss of the year in operating on the market for the raw material, the latter being charged to the manufacturing department at a constant price, conformed from time to time to average market conditions, this price being used also for inventory and cost purposes. In other words, the results of speculation on the market, however legitimate or necessary, should be segregated from the results of the normal operations of the plant.

Axiom 18 Speculative profits and losses should be segregated from those due to the normal operations of a business.

The inventory valuation of stock in process, that is, of stock in a partly manufactured condition, should be such as to cover the prime cost of the material, and of the productive labour already expended upon it, plus a ratable charge for manufacturing expenses. The inventory valuation of finished stock, that is, of stock completed ready for sale, should be on the basis of shop cost, not of actual cost, because the latter includes the cost of selling, and this has not yet been incurred. A paradox, apparent but not real, is created when the cost of a product is substantially reduced, because thereby the inventory value, and therefore the profit of the year, is reduced. If the inventory value at the beginning of the year were £200, and if during the year the cost were reduced 10 per cent., obviously, if the quantity on hand at the close of the year were the same, the inventory value would be £180, thus showing a shrinkage of £20. In the following year, however, this apparent loss would be converted into an actual profit.

Axiom 19 A reduction in cost implies a corresponding reduction in inventory.

The annual inventory may properly include as assets certain items previously classified as expenses. One example of this kind is the premium on unexpired insurance. Another is the cost of a trade catalogue intended to serve, say, for five years. To charge the whole of important expenditures of this kind into the current expense account of the year in which they are incurred would tend to distort its statistical accuracy, and hence would be bad accounting. The proper treatment of such expenses is to determine the period they apply to, and to charge off a proportionate part in each month or year during that period, carrying the remainder in the inventory.

Axiom 20 Expenditures in one year which cover the requirements of several years should be distributed over the years to which they fairly apply.

The inventory valuation of all property other than merchandise should be on the basis of its fair value in the business as that of a going concern, which usually is the cost to replace, with due allowance for wear and tear. An annual inventory of all property, by actual enumeration and count, is indispensable to the proper conduct of any manufacturing business, and in some cases more frequent inventories of the merchandise stock are expedient. Without such annual inventories no determination of annual results is reliable or of much value.

Axiom 21 An annual inventory of all property is indispensable to accurate knowledge and to good management.

The question of depreciation of fixed property enters into all industrial accounting, and should be treated in connection with the inventory. In this, as in all discretionary matters of accounting, the aim should be to find and follow the median line, the mean between ultra-conservatism and radicalism. All fixed property, excepting land, depreciates and tends to become obsolete. Normal repairs and maintenance should of course be charged to current operating expenses, not added to cost or value, and these should fairly be considered in fixing the ratio of depreciation. Where a building or a machine is maintained in perfect condition obviously it depreciates more slowly than one which is neglected. A building may be so maintained as to depreciate little or not at all. The proper rate of depreciation for each class or kind of fixed property is a matter of good judgment, for which no rules can be laid down. It may be as low as 1 per cent. per annum, and in exceptional cases may be as high as 20 per cent. Usually it ranges from $2\frac{1}{2}$ to 10 per cent. When profits are abnormally large the allowance for depreciation may wisely be larger than when they are merely normal, but the normal allowance should be made even when no profit is realised. Under average conditions it usually ranges between 10 and 15 per cent. of the annual profits. A revaluation of all fixed property by outside experts or appraisers, at intervals of five or ten years, is expedient and usually worth its cost. Abnormal increases or decreases in the value of such property, as, for example, an increase in the value of land, or the loss due to the demolition of an obsolete building, should be covered into the surplus account, not into the profit and loss account of the year.

Axiom 22 Valuations of fixed property should be subject to annual review and to fair depreciation.

Finally, the aim and object of every accounting and cost system should be to afford true and accurate information as to facts. It is based on facts; it should embody and present facts, and naught else. To exaggerate facts and to show fictitious profits and values, is no worse than to depreciate facts and to conceal true profits and values.

Axiom 23 An accounting system should present facts, without bias in any direction.

Accounting, in its application to general business affairs, has long been a highly-developed science, but is comparatively a new one in its specialised application to modern industry, with its vast and complex development. The creation of a correct science of industrial accounting and costs should be the desire and aim of all who are concerned with industrial management. To accomplish this, three things at least are needed: (*a*) Clear understanding of fundamental principles (*b*) Definite terminology, generally understood and accepted (*c*) Free interchange of the data of practice, whereby the adoption of sound principles may be promoted, the experience of each may be available to all, the best methods may become established, and, above all, a standard system may ultimately be created.

The accomplishment of these results, by affording complete and accurate knowledge of the essential facts pertaining to industrial efficiency, and to the costs of production, will tend greatly and permanently to promote the development of an industry, and to aid it in securing its full share of the markets of the world.

Miners' Wages Advanced. At a meeting of the Coal Conciliation Board for the federated districts of England and Wales held in London on Monday last it was decided to advance the wages in the federated area by 5 per cent., the advance to be paid to underground workmen and those engaged on the pit bank and screens manipulating coal. The advance will take effect from the second making-up day in January.

MELTING IRON IN THE CUPOLA FURNACE.*

BY RICHARD MOLDENKE.

UNLIKE the smelter and the blast-furnace for the reduction of ores and production of mattes and metals, the foundry cupola furnace has only melting to do. While this looks simple enough and the development has progressed through centuries by cut-and-try methods, there is still much to be learned, and it takes a metallurgist to seek for the reasons underlying the production of defective castings when melting high-grade materials.

There are still other differences to consider. The smelter is run continuously, the cupola rarely so. In the smelter there is some chance for experiment, as rich slags can be returned again, while in the cupola the metal must be good for casting purposes from the first tap to the drop of the bottom, otherwise heavy damage will result. In the smelter the one object sought is the production of metals or mattes with a minimum loss in the slag, whereas in the foundry a variety of castings of different compositions must often be run from the same heat, one after the other.

Experience with the cupola has shown that it is necessary to have the melting done at one place throughout the heat. This is the place of maximum temperature and is readily noticed on looking at the lining by the heavy cutting action of the slag and iron oxide during the melting operation. The design and operation of the cupola must, therefore, conform to the point above mentioned. Once this has been attained, the other considerations resolve themselves into details of construction which will give the least trouble for repairs, with the smallest expense.

The very high temperatures required to melt iron and steel in the cupola, and have the metal sufficiently overheated for casting purposes, render it inadvisable to use water-jackets in the construction of the furnace. It is always possible to patch the lining at the melting zone between daily heats. The balance of the lining is seldom affected enough by abrasion and chemical action to require replacement oftener than once in nine months.

The cupola is practically a shell of steel lined with a refractory material of the proper kind, and provided with a set of tuyeres to allow air to be driven into the fuel and the charges to be melted. It should have the same diameter throughout, as there is no reduction of ore and consequent change in bulk of material to hold. The tuyeres are to be of an almost continuous type, as it is important to keep the belt of maximum temperature above them practically level. The tuyeres are placed at a point to permit of slagging-off below them.

In cupola melting it is necessary to burn the fuel as completely as possible, in order to attain the maximum available temperature. That is to say, the carbon of the coke or anthracite—whichever happens to be used—must be converted to carbon dioxide with as little subsequent change to carbon monoxide as may be possible. If this desirable condition is effected at the point where the metal charge has been placed, melting under the most favourable conditions ensues. The molten iron is superheated properly, and the chances of oxidation in melting are reduced to a minimum.

There follows from the above that in order to get the conversion of the fuel into the maximum amount of carbon dioxide, not only must the bed stop at the point where this is produced and no more fuel allowed over it, but the proportion of air blown into the cupola and the diameter of the cupola must stand in some fixed relation. It is well, therefore, to study the rationale of the process of combustion which takes place in a cupola. Let us suppose that a given cupola has had the bed charged and well-burned through, the first metal charge has been put on, and then the succeeding intermediate charge of coke which is intended only to replace that portion of the bed burned away in melting the first metal charge. The second metal charge is then put on, then coke, then metal, and so on. It is desired to start melting. The blast is put on, and this is what happens: As the air enters through the tuyeres into the fuel, every molecule of oxygen that touches the incandescent fuel picks up enough carbon to make a molecule of carbon dioxide, which travels upward through the incandescent bed. Some of the molecules of this carbon dioxide must naturally be changed to other molecules of carbon monoxide by their contact with more incandescent coke, but as there is a lot of free oxygen present, not to speak of the nitrogen molecules in great abundance, which serve to protect the finished CO_2 from becoming CO, it would take some time and space to travel through to change the bulk of the CO_2 to CO. As a matter of fact, the maximum proportion of CO_2, under ordinary conditions, is reached at 18in. to 24in. above the tuyeres, the bed being sufficiently thick to allow this. If more incandescent fuel is above this then the change from CO_2 to CO is rapid, and the poor melting results quickly noticeable.

While the above described process is going on it will be seen that it is quite easy for some free oxygen to reach a considerable distance up into the charge before being used up in the combustion. In fact, tests on this point by the United States Bureau of Mines have shown conclusively that there is no place in the cupola absolutely free from uncombined oxygen. It was further found that a lot of the air practically escaped unchanged along the lining, where it is just in the right place to become oxidised as it gets into the melting zone.

A further interesting point proved by the investigations of the Bureau of Mines is that there is a central cone in the fuel bed of the cupola above the tuyeres in which there is a formation of CO only, showing that no combustion goes on at all there, which indicates that as the air is blown into the cupola it curves upward, and some of it does not reach the centre directly opposite the tuyeres. The smaller the amount of air going into the same diameter cupola the higher this cone will naturally be, and if it should extend beyond the original height of the bed, after melting for some time, by catching accumulations from the subsequent coke charges, there will be a diversion of the metal charges outward from the centre as they descend, and the melting done in the cupola will be considerably less than the normal amount, besides forcing the cupola to melt in a very uneven manner. On the other hand, the more air blown into the same diameter cupola, the shorter becomes this cone, and it disappears altogether when the air is forced straight through the bed. This is about the ideal condition, and any further forcing of the air by using larger quantities, will unduly increase the melting capacity of the cupola, compelling the raising of the coke bed.

This somewhat involved explanation shows why the amount of air blown into a cupola should bear a certain relation to the diameter of the furnace. Practice is the best guide to this. For instance, the ordinary cupola with a diameter of 54in. inside the lining takes a little less than 30,000 cub. ft. of air to melt a ton of iron. Under the best conditions of practice this cupola has been found to give 10 tons an hour, hence we must provide 300,000 cub. ft. of air to go into that cupola, and see that it really goes in. It is possible to get good results with less air, but then the melting rate drops and this is bad foundry economy. On the other hand, it is possible to get 11 or even 12 tons an hour from the cupola, but this means blowing in the corresponding amount of air, with consequent chances for bad working.

There is, therefore, a safe rate of melting for each diameter of cupola. If a given cupola does not perform in accordance with this rate and the amount of air blown in has been found to be the correct one, then the trouble must be looked for elsewhere. As the blast goes through the fuel bed the gases become hotter and hotter up to the point of maximum proportion of CO_2, and this may be about 3,000° Fah., theoretically. At this point, which is from 18in. to 24in. above the tuyeres, the hot gases should find the charge of metal to melt. If there is fuel still above this point, by originally charging too much fuel, the conversion to CO takes place, with consequent reduction of the temperature. It will, therefore, be seen that from the actual entrance of the air into the bed there is a rapid increase in temperature upward until the maximum is reached, and then a decrease. Experience shows that melting iron is possible for a distance of about 1ft. below this place of maximum temperature, and perhaps 2ft. above it, if the bed were allowed to be so low or so high through improper charging. This effect can be readily understood when it is remembered that the melting point of white iron runs as low as 2,000° Fah., while that of the grey irons is several hundred degrees higher. The iron melts, but in the case of too low a bed it will be insufficiently overheated, besides having been exposed to free oxygen with all the troubles this brings about. In the case of too high a bed the

* Paper presented at the Cleveland meeting of the American Institute of Mining Engineers.

metal has not been oxidised, but is so cold that even dropping through a hotter portion of the bed will not give it the proper temperature for casting.

Experience has taught us how to find the proper height of bed. This height is not a function of the weight of the fuel, but of the amount of travel through it that the air has to perform until the maximum CO_2 has resulted. It has been observed that when conditions in the cupola are just right for the blast to go on, that is to say, when the bed is well burned through, and the cupola charged to near the top with the metal heating up satisfactorily, it should take between 8 and 10 minutes from the commencement of blowing until enough iron runs from the spout to necessitate closing up the tap hole. The melting iron dropping by the peep holes in the wind box will be observed in about 5 minutes after the blast is on, but it takes a little longer to have enough metal to begin running out. If, under these conditions, the metal comes in less than 8 minutes the bed is too low, and should be increased by charging a little more fuel between the metal charges in order to bring it up properly at the time this was observed, and the next day the bed should be made higher. If it takes longer than 10 minutes the bed is too high and should be correspondingly reduced.

Looking at the actual condition of the bed, we find that every portion of it below the tuyeres is simply so much filling intended to give storage space between the lumps of incandescent coke for the molten metal. Above the tuyeres we find the chemical reactions of combustion going on which result in maximum temperature conditions at a given point and at which melting should be done. It further will appear that only the upper few inches of this bed will be of the maximum temperature, and below this the bed is cooler and contains the dreaded free oxygen. Hence the metal charge should be so proportioned that it is melted down completely by the time about 4in. of the bed have been consumed. The correctness of this statement can be observed at any time in looking into the interior of a cupola the morning after a melt. In a well-regulated shop the scoring of the lining is confined to a belt of from 4in. to 6in. In a shop where the reverse conditions exist, the belt of affected cupola lining may be 3ft. high. The latter condition shows a shifting of the melting zone up and down, according as the bed has been allowed to burn away before the succeeding charges of coke came down to replace it, or the bed had been allowed to run by charging too much coke between the charges of metal.

The inferences that must be made from the above are that the smaller the charge of metal and the oftener repeated, the less the shifting of the melting zone up and down in the cupola and that it is a serious mistake to adopt the almost universal rule followed in the United States to make the first charge twice as heavy as the succeeding ones. Where this is done, it is patent that double the amount of coke must have been burned away from the top of the bed, only half of this being replaced by the intermediate charge of coke, and from the second charge of metal the melting is done at a lower point in the cupola. It is difficult to instil this point into the minds of cupola men and even chemists. They see a big pile of coke go into the cupola for the bed, and of necessity hold that a big lot of iron should go on it, forgetting that only the very upper portion of the bed does the work whether the bed is big or little. European practice is more rational in this respect, for not only are cupolas of small diameter used with consequent effective penetration of blast, but the charges are very small and there is no large first charge.

While the weight of the coke for the bed is not essential, it is a very important factor for the intermediate charges. That is to say, once the proper height of the bed has been found for a given coke, the replacement of what is burned away in melting each charge is a definite function of its composition and somewhat of its cellular structure. Every time the brand of coke is changed it is necessary to try out the melting time for first iron, in fact in well-regulated shops this is done every day, unless the shop custom is to keep the breast closed during the burning through and blast on, when it is sufficient to make the above described time trial once a week. It is also necessary that the fuel for the bed should be perfectly dry, though this is not essential for the upper charges, provided due allowance is made for the water in weighing, as the carbon content is required in the right proportion.

It is, therefore, well to use another experience figure for the weight of the intermediate charges of fuel. This is one-tenth the weight of the metal charged above it and which it is to melt. A good, high fixed carbon coke can melt more than 10 times its weight, or the ratio is, say, 11lbs. of metal to 1lb. of coke, while a high ash coke works the other way. Hence we have got to the point where in trying out the melting conditions required for a cupola, the first iron is wanted at, say, 8 minutes, the first charge of metal as small as all the others, and the charges of coke between these metal charges one-tenth in weight. It now remains to fix the size of the charges of metal.

Since about 4in. of the coke bed only should be burned away in melting the metal charge above it before the next coke charge comes down, it is apparent that the proper size of the metal charge should be 10 times the weight of 4in. thickness of coke in the cupola. The best way to ascertain this weight is to lay a ring of cupola blocks or firebrick on the cupola charging floor, of the diameter of the cupola, and 4in. high. Fill this space with coke and weigh it. Ten times the weight is the amount of metal to be charged.

Inasmuch as during the course of a melt the cupola becomes hotter and the upper charges well heated, less coke is required between the charges, and here the experience of the foundrymen comes into play. The easiest method of determining this question is to observe the rate in melting. That is to say, if a given cupola melts 10 tons an hour for the first hour, and only 9 tons the second hour, a gradual and slight reduction of the intermediate charges of coke is in order until the melting rate is restored and even accelerated. Continued observation quickly overcomes this difficulty.

Oxidised iron is very difficult material with which to obtain good castings. It seems that when the melting iron gets into portions of the cupola where free oxygen is present, it is affected thereby, and the result is a higher freezing point. The metal loses its life and cannot safely be held for any time. Moreover, it contains gases which come out at the moment of set, with the result that the castings show evidences of pin holes, heavy shrinkages, and even cracks from loss of power to accommodate themselves to internal strains while the metal is setting. And still worse, the pin-holes often do not appear until the skin of the castings is removed by machining. The reason for this is that when the mould is poured, the metal immediately in contact with the sand sets first, and in doing so passes its contained gas through it. Once this skin has formed, further gases attempting to get out are shut off, rise to the top, and will remain just under the skin of the cope. Metal of this kind always shows defects when the cope portion is planed off. Since this condition is entirely due to the oxidation of the metal, it is important that the charging of the cupola be done very evenly and regularly and not to charge the pigs around the lining and the scrap in the centre.

The subject could be extended still further by giving many and varied examples from actual experience, but enough has been said to indicate that the cupola is by no means the simple contrivance that it is supposed to be, and that there are refinements in practice which take into account peculiarities in fuel, metal, and even the air used for combustion purposes.

In summing up the subject, the following conditions should be observed:

That the proper amount of air gets into the cupola for its capacity.

That the bed coke is dry and well lighted before charging.

That the bed is of proper height to give first iron in from 8 to 10 minutes.

That the metal charges are of equal weight.

That the metal charges are no larger than that requiring coke enough just to cover the metal below.

That the coke charges are so adjusted to the metal charges that, throughout the heat, the melting zone remains stationary and at the right point.

That the blast volume (not pressure) never changes throughout the heat, since any variation will immediately change the position of the melting zone.

That the charges are evenly distributed: First, the pig iron over the entire bed, then scrap also over the entire bed, then coke. If steel is used, put it on before the pig. Never use thin scrap steel.

That only one row of tuyeres be used, and these should be of sufficient size. If a second row is available, open only a very few of them, so as not to disturb the position of the

melting zone, while giving extra air to burn the CO that may form in the furnace.

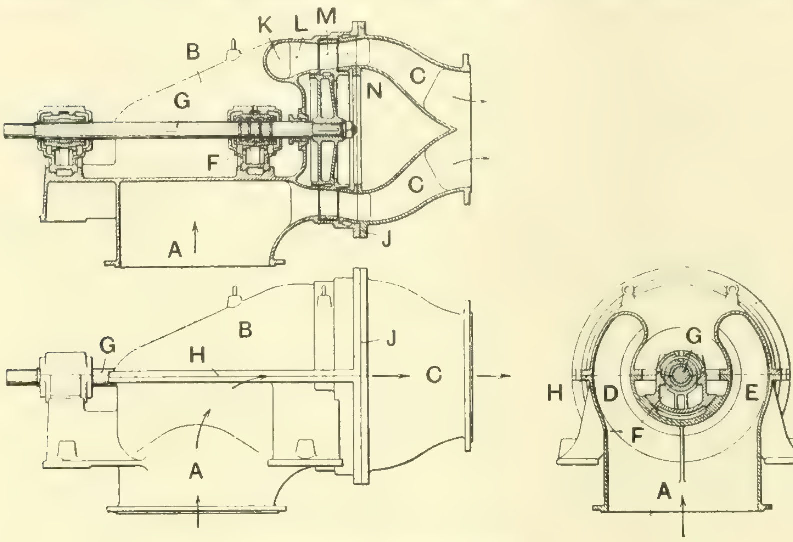
That the melting rate be watched and the intermediate coke charges adjusted accordingly.

That the charging of very large pieces of metal be avoided, since these very often deflect the gas currents and bring about an uneven burning of the fuel.

Heavy coke, with small percentages of cell space, can stand large charges, anthracite coal being the extreme in this connection. Light cokes, with large percentages of cell space, must have very small charges to get best results.

SULZER'S TURBINE PUMP.

We illustrate herewith a design of horizontal turbine pump, the invention of Messrs. Sulzer Bros., Winterthur. The lower part A of the casing which constitutes the suction branch is bifurcated at its junction with the upper part B, two branches D and E being thus formed, between which is arranged the bearing F for the shaft G of the rotor wheel. The parts A and B are connected together by bolts passing through a horizontal flange H. The rear part C is connected



Sulzer's Turbine Pump.

to the parts A and B by means of a vertical continuous flange J which surrounds this member. The water from the annular chamber K, after having passed through the suction conduit L, passes into the rotor wheel M, and thence into the pressure branch C through the pressure or outlet conduit N. Owing to the division of the casing above described, it is possible to remove the parts separately, or to obtain access to the whole interior of the pump, by lifting off the upper part B of the casing without it being necessary to remove the pressure or the suction branch. Moreover, owing to the bifurcated shape of the suction branch, the bearing next to the rotor wheel can be brought quite close to the rotor wheel, so that if the wheel is supported only on one side, the pump spindle overhangs or projects only a short distance beyond the bearing. Finally, the construction of the pressure branch in the form of an axial extension of the pump casing, prevents disturbing currents from being set up when the water passes into the pressure pipe.

THE INSTITUTION OF ELECTRICAL ENGINEERS AND RESEARCH WORK.

The committee of the Institution of Electrical Engineers appointed to consider the question of research recently submitted a report on their work. This report has now been adopted by the Council. After considering the scope and scale of the research work which might be undertaken by the Institution, the committee are of opinion that it is desirable to avoid overlapping the work of other societies, such as the British Association, the Royal Society, and other similar bodies; they therefore suggest that the work of the Institution be confined as far as possible to the following lines: (*a*) The organisation and correlation of research work in electrical engineering; (*b*) the origination and supervision of specific researches in subjects connected with the electrical industry, and the allocation of grants in aid of the same. The organisation and correlation of the research work carried on within the sphere of influence of the Institution should include the following: (1) The establishment of a general committee for research to which investigators would be invited to send particulars as to the subject and character of the researches they are undertaking. Members of the Institution, especially those connected with the manufacturing side of the industry, would also be invited to communicate to this committee any special difficulties they had encountered which called for investigation, and to make suggestions for subjects for research. The general committee would thus act as a species of "clearing house" for research topics, receiving suggestions from various sources and sending them on after consideration to the most suitable quarters. (2) The collection and publication of particulars of plant available for special testing and investigation work in the various laboratories, together with a list of the subjects in which researches have been carried out. (3) The compilation and publication of bibliographies of specific fields of research. The committee consider that it is desirable that the Institution should originate and direct researches in certain subjects, and suggest that the General Research Committee should have power to appoint sub-committees of experts to deal with researches in selected subjects. In the first instance, a series of investigations might be initiated on "The Electrical Properties of Materials," which would deal with such matters as magnet steel, copper, carbon, paper, rubber, mica, porcelain, oils and varnishes, &c., on all of which fuller data are required.

NICKEL-BRONZE MIXTURE FOR HYDRAULIC CASTINGS.

The making of bronze castings to stand hydraulic pressure is, says "The Brass World," a matter which often perplexes a brassfounder. He may be able to make good castings with a fine surface, but when the castings are tested leakage results. It has been found that a special mixture is better for hydraulic castings than the ordinary composition or the well-known 88-10-2 bronze. A casting which has a good superficial appearance may not stand the pressure, and for this reason a mixture which has the necessary closeness of grain is required. It is not a question of tensile strength in the castings, as this has been found less important than the grain of the metal; and the patterns will be found of sufficient thickness to stand the pressure. Those who design such patterns know well that there is nothing to be gained in making the walls too thin, and it is invariably the case that a sufficient thickness is given them. The problem, then, is one of mixture and good foundry practice. Even with the mixture herewith given, poor foundry work cannot be tolerated.

The following mixture for making hydraulic castings has, according to our contemporary, been in use for some time in one of the large foundries in the United States and has proved very satisfactory for this purpose. It has been used on castings which had to stand a pressure of 3,000lbs. to the square inch hydraulic pressure and for this purpose was found excellent. The mixture is as follows: Copper, 83lbs.; tin, 5lbs.; zinc, 5lbs.; lead, 5lbs.; nickel, 2lbs.

The nickel in the mixture is the metal that produces the good qualities for hydraulic work. To make the mixture the nickel should be put into the crucible with a small amount of the copper and the two melted together. Make sure the nickel is melted and keep well covered with charcoal while the melting is going on. Then add the rest of the copper and melt in the usual manner, afterwards adding the zinc, tin, and lead. Stir well in order to thoroughly mix the ingredients. The metal is poured at about the same temperature as composition.

Fatal Gas Producer Explosion.—An inquest was held at Rotherham on the 3rd inst. relative to the death of a gasman, who was fatally burned at the works of Steel, Peech, and Tozer, Ltd., on December 24th. The man was employed in connection with a gas producer in the steelworks, and on Christmas Eve was engaged, along with another gasman, in lighting a gas producer, when an explosion occurred and deceased was so badly burned that he died a week afterwards. The jury returned a verdict of "Accidental death."

COPPER ALLOYS FOR MOTOR-CAR SERVICE.*

BY W. H. BARR.

IN offering a paper on copper alloys, one approaches a subject of such magnitude that it can only be treated briefly, in a manner that may prove of interest and service to automobile engineers. The basic ingredients of bronze and copper alloys are, of course, copper, tin, zinc, and lead, and we will consider these metals from a viewpoint somewhat unusual.

In bronze and brass alloys, copper is the predominant metal, being the element with which we can best alloy smaller quantities of other metals. The essential characteristics of copper are to impart strength and toughness, and in ornamental work, varying degrees of rich, red colour. It is the best conductor among the metals of both heat and electricity, slightly excelling silver in the latter respect. Chemically-pure silver was, for years, believed to have the highest electrical conductivity of all the metals, and accordingly was the basis for the 100 per cent. standard. Recently, however, copper has been produced in so excellent a state of purity as to indicate an electrical conductivity of 104 per cent. The specific gravity of copper is 8·82; and the melting point 1,981·5° Fah. The tensile strength varies with the physical conditions, producing the following results: In cast copper, the tensile strength is 26,000lbs. per square inch; in bolts, 34,000lbs.; and in wire, 55,000lbs. The tempering of copper has for years been considered a lost art, but among the latter-day scientists, the unity of opinion is that this climax of the art never existed.

Tin is a white metal with a distinctly yellowish tinge, and can be rolled into very thin sheets, but its low tenacity prevents its being drawn into wire. Its specific gravity is 7·29 and its melting point 449·4° Fah. It has a distinctly crystalline structure and emits a peculiar crackling sound on being bent back and forth, due apparently to the rubbing of the crystals on each other. The smelting is a comparatively simple operation, as the oxide is readily reduced by carbon at a red heat. The purest metal is obtained from reverberatory furnaces. This is further refined by liquation, which consists in subjecting the metal to a low temperature on a sloping hearth, where the tin, having a low melting point, runs out, leaving the impurities behind.

Tin produces a decided tempering effect in combination with copper, varying in proportion as it is used. Above 25 per cent. tin, the alloy is too hard and brittle for use. The true bronzes are alloys having these two elements as their main constituents. Up to about 10 or 12 per cent. tin the material is not affected by quenching. Above that percentage quenching to the proper temperature renders the alloy softer than if slowly cooled, being directly opposite the effect which such treatment has on steel. Tin also has a high colouring effect on copper, a very small quantity being distinctly discernible. Tin in combination with the brasses or copper-zinc alloys, when present in small amounts, renders the alloy more sound, more fusible and capable of taking a better polish.

Zinc, commercially called spelter, is the next important metal. It is of a bluish-white colour, of a decided crystalline nature, and at ordinary temperature, quite brittle. Between 250° and 300° Fah., however, it is malleable enough to permit of rolling into thin sheets and drawing into wire. Zinc is not found in a free metallic state, but is obtained from its ores, which are chiefly sulphide of zinc and carbonate of zinc. The concentration of the ore is attended with considerable difficulty, as the associated impurities are generally of about the same weight as the ore. The specific gravity of cast zinc is 6·87, and its melting point 786·9° Fah. It is a poor conductor of both heat and electricity.

Of the different metals that we are considering, zinc is the only one that can, of itself, properly be called a bearing metal. Used unalloyed for bearings where strength is not essential and its brittleness is not objectionable, there is probably nothing superior to it for wearing qualities.

Zinc in combination with copper produces the brasses. Very small additions of zinc render copper suitable for casting. Larger additions cause gradually increasing hardness, but not to as marked an extent as tin. Nearly 50 per cent. zinc can be added before an alloy too brittle for use is obtained. With increasing zinc contents, the strength and elongation, as well as the fusibility of the alloy increases. The colouring effect of zinc on copper is not as immediate as that caused by tin.

In the high copper-tin bronzes, zinc is used in small quantities of about 1 or 2 per cent., mainly for a cleansing effect. It improves the fluidity of the metal, thus making sharp, clean castings, free from blow holes. With a higher percentage, the hardness and strength of the bronze decreases, and the brass-like qualities thereby imparted become apparent.

The specific gravity of lead is 11·35, melting point 621° Fah., and the tensile strength 2,000lbs. per square inch. Lead, in combination with copper, is exceedingly difficult to introduce in its best form and remains undissolved as inter-crystalline material. It is, therefore, not an alloy, but rather a mechanical mixture. The action of the lead in combination with a copper-tin bronze acts as a lubricant, the small, free globules of lead in a bearing being very beneficial. Although lead makes the alloy dense and malleable, it has a decidedly weakening effect in that its globules break up the continuity of the crystals. A high lead bronze, 10 per cent. and more, when broken, will show a grey fracture as a result of breaking through the weaker lead globules and not through the crystals of the copper-tin mixture. The same fracture, if finished and polished, will show the proper red colour of the particular alloy. In brass, lead also acts as a lubricant and prevents fouling of the tools in working.

Some elements, such as arsenic, antimony, and sulphur, have a detrimental influence on bronze, but there is one which has a decidedly beneficial effect, and that is phosphorus. The function of phosphorus on a bronze is that of a deoxident. It cleans the metal from oxides of copper and tin, and if the correct amount is used for this purpose, none remains in the finished alloy. By the removal of these oxides the bronze is rendered more fusible and better castings are possible. Larger additions of phosphorus harden the metal, but at the expense of toughness. The production of various qualities of phosphor-bronze depends more upon the proper proportioning of the various ingredients than upon the quantity of phosphorus.

One of the problems which must be contended with by the sales department of a brass foundry is the lack of information about phosphorus, which results in ridiculous specifications, often asking for a phosphorus content as high as 10 per cent. The specification of phosphorus can with safety be left only to the metallurgist, instead of the ordinary brass foundry foreman, who usually relies entirely upon guesswork. Phosphor-bronzes should be secured only from companies of reputation, who make a speciality of their manufacture.

High copper alloys, as related to motor-car construction, may be divided into four classes: Soft phosphor-bronze, hard phosphor-bronze, red brass, and yellow brass.

Soft bronzes in general are low in phosphorus and high in lead, the former being used solely as a purifying or deoxidising agent. This class of bronze can only be considered for bearings, the high percentage of lead reducing the tensile strength of the alloy, so as to make it unsuitable for severe strains. Under this head may be mentioned one of the standard alloys, 80 copper, 10 tin, and 10 lead. This combination is generally used throughout all motor car construction, and present practice among the best makers finds use for the alloy in a number of places. It is difficult to recommend this or any other alloy to render the best service in any part of a motor-car without the specific knowledge of conditions covering its use. Before making an intelligent selection it is necessary to know the bearing pressure, character of lubrication, and amount of vibration, as well as the nature and quality of the steel which is used in the rotating piece.

Those phosphor bronzes commonly described as hard are generally high in both phosphorus and tin, and low in lead contents. In those cases where the phosphorus content runs as high as 1½ per cent., the tin content is necessarily under 12 per cent., or the alloy would be too brittle. The reverse is also the case and where alloys contain a mixture of approximately 80 copper and 20 tin, the phosphor contents should not be over 0·5 per cent. An alloy of this character is used to withstand heavy pressures and has no place in motor-car construction.

Among the high copper-tin bronzes may be classed the gear bronze most generally used, consisting of 88 or 90 copper, and from 12 to 10 tin. A few prominent manufacturers of

* Abstract of paper read before the Detroit Section of the Society of Automobile Engineers.

bronzes have their own special formula, which in some cases may be superior to a formula of 88-12, or its approximate. The composition of 90 copper and 10 aluminium has proved one of the most successful gear bronzes on the market, having an average tensile strength of 60,000lbs., often reaching 65,000lbs. per square inch. It has wonderful bearing qualities. It has not been generally used owing to the difficulties encountered in its manufacture, only one or two makers having solved the problem of producing perfect castings. The alloy of 88 copper, 10 tin, 2 zinc, fills many requirements most satisfactorily and for all-round use is hard to improve.

Red brass, commonly known as composition, contains a maximum of 85-86 per cent. copper. In this way it can be differentiated from the bronze class. Too often, red brass is only an excuse for a visit to the scrap pile on the part of mediocre brass foundrymen, where the scrap, selected with varying degrees of care, depends largely on what the customer will accept. Fortunately, this condition is being remedied, and that type of brass foundryman is being eliminated, through the demand by automobile engineers for a brass of uniform colour and texture. One alloy which has given excellent satisfaction is 85 copper, 5 tin, 5 lead, and 5 zinc. This alloy has an excellent colour and may be used in motor-car construction where severe bearing necessities or great strength is not a requirement.

Yellow brass may be sub-divided into two classes, one being the type of brass used generally for ornamental purposes. The other is manganese-bronze, in which the percentage of copper and zinc runs close to yellow brass. Its tensile strength and other remarkable properties are brought about by the use of small quantities of iron, manganese, aluminium, and tin, in varying proportion. Manganese-bronze being very generally used either for experimental or permanent construction, should not be passed without comment. If it is the intention to use the casting where rigidity is required, the manufacturer should be so advised. By slightly changing the composition of manganese-bronze, it is possible to alter its rigidity and consequently, its ductility, to a marked extent. In specifying for manganese-bronze castings, it is wise to adhere to established brands, particularly where the work is being done by your own or a local foundryman who perhaps lacks the metallurgical knowledge necessary to produce or even judge a good ingot metal. Manganese-bronze may be used for practically all brackets, foot levers, radiator braces, and all external parts requiring strength in the body. This covers the brakes, lugs, levers, hubs, spider, steering yokes, fan pulley, dust covers, plates, brake lugs, windshields, handles, supports, hinges, buttons, latch, foot adjustment, quadrant, and any parts, not including bearings, which require the strength of high-grade steel or drop forging.

The correct and practical solution of the severe bearing requirements on the modern high-speed gasoline engine is of the utmost importance. In designing engine bearings, there are two important conditions that must be taken into consideration. First, the selection of a proper alloy, having the requisite anti-frictional qualities, and secondly, the selection of a metal having the necessary physical properties as regards strength and resilience. The latter property is the one too often neglected. A soft babbitt may have the anti-frictional requirements necessary for gasoline engine service, though owing to its plastic nature, its physical properties render it unsuited for the work. On the other hand, a bearing made entirely of steel would have the necessary strength and resilience, but would not be anti-frictional. These anti-frictional qualities are so obviously imperative that in nearly every case these have been considered at the expense of the mechanical or physical properties of the bearing. Soft babbitts have been discarded, and for the reason stated, harder babbitts have been substituted; in many cases, die-cast bearings have become generally used as crank bearings in some classes of motors.

In the light of the foregoing facts, it is not a difficult task to design the ideal bearing, for it resolves itself into combining the best anti-frictional qualities with the highest physical strength and resilience. These qualities have not been found in any one metal or alloy now known. It, therefore, becomes necessary to unite these characteristics in a bearing, and this is done by adopting the old-fashioned babbitt-lined bronze shell of a modified design. For the bearing surface requirements, we select a high tin, so-called genuine babbitt, containing about 90 per cent. tin, and approximately 5 per cent. each of antimony and copper. This alloy adheres readily to the bronze shell and in its formula is close to several well-known brands. A variation of 1 per cent. in any of the constituents will not materially affect the result. For the necessary physical property, we select a copper-tin bronze having high strength and resilience. The constituents of this bronze should be so proportioned that upon cooling from the molten to the solid state there is no eutectic formed, that is, no small portion of the alloy may have a lower melting point than the greater part of the mass.

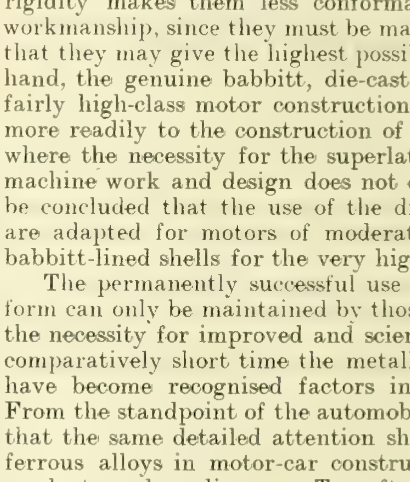
The alloy should possess perfect homogeneity, and it should not deteriorate when subjected to alternating mechanical strains and changes of temperature, as would an alloy which is not free from one or more eutectics. Furthermore, strength should not decrease with an increase of temperature. It should be strictly a resilient metal, in that it should have the least tendency for crystallisation under shock and mechanical strains.

The bronze-babbitt-lined shells are naturally adapted to the construction of the highest class of motors, in that their rigidity makes them less conformable to a lower grade of workmanship, since they must be machined accurately in order that they may give the highest possible service. On the other hand, the genuine babbitt, die-cast bearings are suitable for fairly high-class motor construction, as they lend themselves more readily to the construction of a moderate-priced motor, where the necessity for the superlative degree of accuracy of machine work and design does not exist. It may, therefore, be concluded that the use of the die-cast babbitted bearings are adapted for motors of moderate price, and the bronze-babbitt-lined shells for the very highest class.

The permanently successful use of bronze or brass in any form can only be maintained by those engineers who recognise the necessity for improved and scientific methods. Within a comparatively short time the metallurgist and the laboratory have become recognised factors in brass foundry practice. From the standpoint of the automobile engineer it would seem that the same detailed attention should be given to the non-ferrous alloys in motor-car construction as is given to steel products and appliances. Too often the decision as to what brass or bronze may be used is left to the purchasing department, where price alone usually governs the selection.

METHOD OF ROTATING SHAFTS OF MACHINE TOOLS.

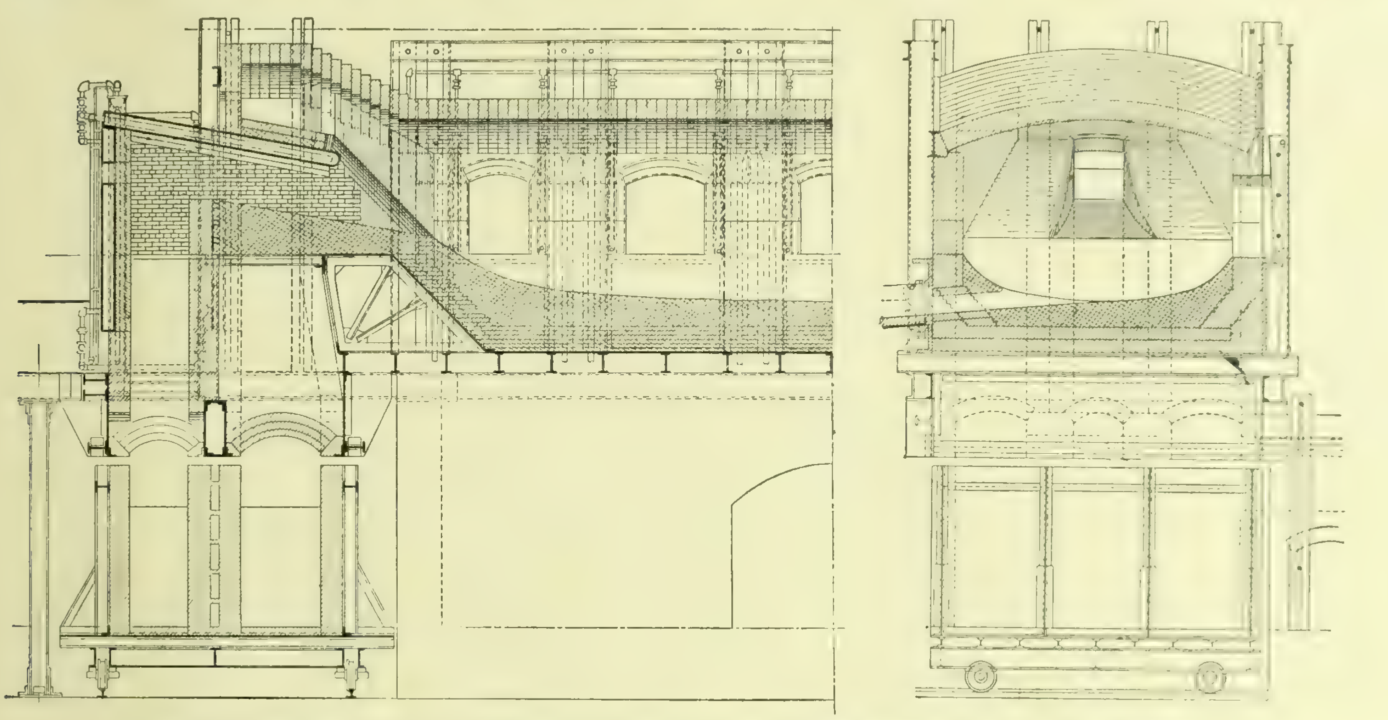
THE accompanying illustrations show an arrangement recently patented by Messrs. Alfred Herbert, Ltd., Coventry, for rotating the shafts of machine tools by hand, particularly where the shaft is also at times rotated by power, as in the case of milling machines, &c. To enable delicate adjustments of the shafts to be obtained it is desirable that a hand wheel be fitted to the shaft, and for quick winding a crank with a handle is preferable. In the arrangement illustrated, the crank is mounted outside the hand wheel and the handle moves axially to engage the hand wheel. To the shaft A is fixed a hand wheel B, the rim of which is provided with a number of notches or holes C. On the shaft is loosely mounted a crank E, the outer end of which carries a handle F which can be caused to engage with the notches in the rim of the hand wheel by the actuation of a sliding pin H contained within the handle grip and pushed into place when the handle grip is slid towards the crank. It will be seen that directly the grip is released the catch becomes disengaged and the handle is freed from the wheel, which may continue to revolve or not. The wheel is always ready for operation to engage for minute adjustments and the effort required by the operator is very small.



ARRANGEMENT FOR ROTATING SHAFTS OF MACHINE TOOLS.

THE BLAIR REMOVABLE SLAG-POCKET.

In the usual operation of an open-hearth furnace for the manufacture of steel, the resultant filling of the slag-pockets with slag necessitates periodically stopping the operation of the furnace for cleaning out these pockets. This cleaning is not only destructive of the brickwork of the pockets and expensive in that way, but the necessary interruption in production by the furnace augments the expense by the consequent loss of product. This expense is particularly heavy in the operation of basic furnaces. To meet the problem a slag-pocket structure as a removable portion or section of the furnace structure has been developed by the Blair Engineering Company, New York and Chicago, whereby it may be readily and relatively speaking quickly removed when filled, and as readily replaced by an empty one. The accompanying illustrations, for which we are indebted to "The Iron Age," show a longitudinal vertical section of one of the two similar ends of an open-hearth furnace provided with this improvement and a sectional view of the furnace at one end. The drawings also show the furnace equipped with Blair ports.


SECTIONAL ELEVATIONS OF A 60-TON OPEN-HEARTH FURNACE WITH BLAIR PATENT PORTS AND REMOVABLE SLAG POCKETS

The slag-pocket structure consists, in its preferred form, of a wheeled carriage for convenient moving on a track provided in the proper position at each end of the furnace. It has metal posts, suitably braced, rising at intervals from the carriage bed to provide a framework for the brick walls forming the slag-pockets. The lower ends of the port down-takes are provided with suitable metal binding for supporting the slag-pocket arches at the lower ends of the down-takes, whereby these arches are separate from the slag-pocket walls and not dependent on them for support. The dimensions of the structure are such as to adapt it to fit under the down-takes of the flues, registering its pockets therewith to receive the slag produced in the operation of the furnace and filling out the structure of the latter, as when the slag-pockets are formed integral therewith in the usual way.

On placing a slag-pocket carriage in position a narrow opening is left between the top of the pocket-walls and the down-take walls and a similar opening between the wall of the flue leading to the regenerative chambers and the adjacent wall of the pocket-structure. These spaces are then temporarily closed by brcking them up to form tight joints connecting the slag-pockets with the port down-takes and with the regenerative chambers. When the slag-pockets are filled, the bricks are knocked in to destroy the bond between the carriage-walls and the permanent furnace walls, and without disturbing any other part of the furnace structure, the slag-pot carriage is withdrawn to be replaced by another, whereupon the spaces are again bricked up. The joint in the walls may be made by placing a layer of ganister on top of the slag-pocket walls and shoving this whole box up tight against the upper portions of the walls by means of four screws at the corners of the carriage, blocking it in position by means of wedges or supports at the bottom of the carriage. In this case, where the amount of the lift is so small—say an inch or two—and where the operation occurs only once in two or three months, the screws are simpler and better than a hydraulic ram for the purpose. This would make the operation similar to putting the bottom on a Bessemer converter.

Instead of requiring in time, for effecting the removal of the slag and rebuilding the slag-pockets and down-takes, as heretofore, from a week to 10 days, with the attendant loss of the product of the furnace and that due to the expenditure of a very considerable amount of labour and fuel to bring the furnaces back to melting temperature, the whole operation of removing the slag and restoring the slag-pocket equipment in a furnace in accordance with this improvement may, it is stated, be accomplished in a few hours, thus enabling a large portion of the heat of the furnace to be retained, so that the furnace may be got back to normal working conditions with very little delay and expenditure of labour and fuel.

Machine Tool Design.—At a recent meeting of the Cleveland (Ohio) Engineering Society, Mr. E. P. Bullard, junr., President of the National Machine Tool Builders' Association, delivered on address on "The New Era in Machine Tool Design." There was not, he said, the difference between the machine tools of to-day and the machine tools of 10 years ago that there should be. They had not in all cases kept up with the times. Many of the machine tools were identical in detail with what they were 10 years ago. Firms building machines of that kind could not hope to keep up their trade. The machine tool of to-day must meet the conditions of to-day. Control was, he considered, the essence of machine tool design, and played the largest part in the production of work. The machine tool must not merely be started and stopped; it should be started precisely at the right time under perfect control and should be stopped exactly at the right time and should stay stopped until it was again started. The machine tool should do the work, and the operator should use his energy solely in directing it. He should not be called upon to spend his valuable time or his mental energy in using an oil can around on 50 or 100 different holes which were supposed to be oiled. He should not be called upon to shift dangerous belts or move heavy parts. That could be done by power. He believed that five years from now forced lubrication would be adopted on all machine tools.

MODERN STEEL FOUNDRY PRACTICE.*

BY SAMUEL R. ROBINSON.

In acid practice the general construction has changed but little from the furnace of ten years ago. In building the usual 25-ton furnace it is now customary to put three rows of brick on the bottom plates and 18in. of brick over the chill plates. The corners are not left square, but are "filleted," *i.e.*, they are filled up with brick to prevent a breakout at this point. Charging machines are used on all the later furnaces from 20 tons upward. If space will not permit their use the furnace is served by a charging crane. The checkers are independent of the furnace; that is, they do not support the weight of the furnace. All furnaces are built entirely above ground with the top of the flues on a level with the ground.

The use of 50 per cent. electro ferro-silicon in place of the 11 per cent. alloy is general now; preferably in the furnace, but quite often in the ladle. The writer's opinion is that all additions should be made in the furnace as far as practicable, as the furnace is the proper place to make the steel and not the ladle.

Fuel oil is used extensively, in most cases being atomised with air at a pressure of 45lbs. of oil and 30lbs. of air. The usual plan is to have the pressure on the oil storage tank. Steam as an atomising agent is very seldom used, as it is now generally known as a mistake to think that there is a gain in heat through its dissociation.

Small open-hearth furnaces are coming into more general use; that is, from 5 to 10 tons capacity. Twelve thousand pound heats are now being made in this type of furnace, making 140 openings of the stopper and requiring 1 hour to pour. The life of such a furnace should be 500 heats without repairs.

The latest development in small open-hearth furnaces is the Carr furnace, of about 2 tons capacity, with the entirely new principle of pouring directly from the furnace into the moulds. On account of the high temperature obtained this furnace allows of the manufacture of castings of thin section and intricate design. The metal is very pure, as there is no contamination except from the flame, which is usually natural gas, although of course producer gas or oil can be used.

The accepted side blow practice consists in the use of a lower silicon, say, from $1\frac{1}{4}$ to $1\frac{1}{2}$ per cent., with a blast pressure of $2\frac{1}{2}$lbs. to 3lbs. to the square inch. This is found to give quieter blows and hotter metal.

The biggest factors in successful converter operation are: (1) clean hot iron from the cupola, and (2) fast working. Do not skimp on coke, and arrange to run so fast that it will not be necessary to shut the blast off the cupola. The practice quite often now is to "cut the flame short"; that is, to turn the vessel down just before the drop of the final flame and then, without any final addition of iron from the cupola, adding lumps of wet ferro-manganese to the converter, and 50 per cent. ferro-silicon to the ladle.

The old firebrick tuyeres have been replaced by ordinary iron pipes, which are rammed up in position with ganister and are left in during blowing; when they burn off they are simply shoved further in and a new piece of pipe placed on the back end. The vessel is usually lined with silica brick, using 9in. brick on the bottom, side-arch up to the tuyeres, wedge-brick up to the dome, and key-brick for the dome. Ganister is sometimes used, being mixed with a small amount of fireclay and rammed around a form. The cupola is lined with brick and usually patched with mica-schist or sandstone.

Chill pig iron is not used to advantage in cupolas under 42in. inside the lining. For the smaller size cupolas it is better to use sand pig broken into four pieces if possible. The charge usually consists of 70 per cent. pig and 30 per cent. scrap steel, although 50 per cent. scrap is carried regularly in some shops. In using 50 per cent. scrap the metal has to be handled very rapidly as it has not much life in the ladle. Eleven per cent. ferro-silicon is used in the cupola at times to bring up the silicon when the percentage of silicon in the pig is low. In fact, it is possible to melt and convert a charge of all scrap and 11 per cent. ferro-silicon without any pig whatever.

Lip pouring is the usual practice with converter steel, although bottom pouring, in a green sand moulding shop using matchboards and ramming up all work on the floor in regular rows, has many advantages. The usual practice is to use the same ladle with the original nozzle as often as possible, using a new stopper each time. As many as six blows can be poured through one nozzle at times. In some shops the nozzle is changed as well as the stopper after each blow.

The Stock oil-fired converter does away with the cupola altogether, melting the charge of pig and scrap in the vessel direct with an oil flame, and when at the required temperature, blowing the heat as in regular side-blow practice. Very few people realise the loss in the cupola as ordinarily conducted. The saving of heat by not having to transfer the iron from the cupola to the converter, also the reserve of heat left in the converter from a previous blow, must be quite an item. The metal can be made very hot and it is very pure, as there is no contamination from the flame. The inventor of this process claims that a charge of $2\frac{1}{2}$ tons can be melted and converted in $1\frac{3}{4}$ hours with a fuel consumption of 70 galls. of oil and a power consumption of 50 kw.

The greatest improvement has been in the direction of a more refractory sand for facing by a careful selection of good silica sand and pure fireclay. Drying the moulds is watched more closely and a continuous record of the oven temperature is kept at all times. Recording thermometers for core ovens are now in general use also.

All shop inspection should be in the hands of competent men and all castings should be checked against the blue print and inspected for imperfections before they are put up to the customer's inspector. The manufacturer has a fear of some present-day inspection, and consequently does not go after business that he otherwise would if he had the information at hand that would show him just what he had to look out for.

* Abstract of paper read before the American Foundrymen's Association.

CORRESPONDENCE.

Condenser Design.

To the Editor.

Sir,—Referring to the instructive article on page 802 of your issue of December 27th, and as the subject of maintenance of high vacuum is always of interest to practical engineers, I think the following report will be read with interest by your readers, especially in relation to the information contained in the diagram, Fig. 5. In June, 1911, my company supplied for an air pump manufactured by Messrs. W. H. Bailey & Co., Ltd., of Manchester, some air pump valves, which were put into work at Messrs. Martineau's sugar refinery, Whitechapel, in November, 1911. The pump is now undergoing its annual inspection, and the valves have been taken out. They have been re-measured, and it is found that, although the pumps have been maintaining a vacuum of over 29in. night and day for 11 months, the valves have worn on one side less than $\frac{3}{64}$in., and I have every reason to believe that a period of at least twice as long as they have already lasted will elapse before they are worn out and unfit for use. The good result attained has been to a large degree due to the fact that the valves were fitted with the patent Anchor bush, which absolutely eliminates any tendency of enlargement in the central hole, thus maintaining a high vacuum, avoiding expense of early stoppage of machinery, and the possibility of spoiling the material in process of manufacture. The natural corollary is, therefore, if a high vacuum and freedom from breakdown are wanted, use Dermatine valves, fitted with the patent Anchor bush.—Yours, &c., C. R. C. HART.

Managing Director.

Dermatine Company, Ltd.,
95, Neate Street,
Camberwell, London, S.E.

Electric Lighting Provisional Orders.—The official list of applications for Provisional Orders deposited with the Board of Trade under the provisions of the Electric Lighting Acts, 1882-1909, show that 47 applications were made in 1912, the majority of these dealing with urban districts.

USE OF OIL FUEL IN THE NAVY.*

BY ENGINEER-IN-CHIEF H. I. CONE, U.S.N.

THE advantages of oil over coal as a fuel for naval vessels are: An evaporation per pound of fuel in the ratio of about 14 to 9, and per square foot of heating surface in about the ratio of 10 to 8. Fuel can be taken aboard more rapidly, without manual labour, and without interruption to the routine of the ship. The problem of fueling at sea is solved. Steam for full power can be maintained as readily as for lower power. A vessel burning oil is capable of runs at full speed limited in duration only by the supply of the fuel. There is no reduction in speed due to dirty fires or to difficulty in trimming coal from remote bunkers, or to exhaustion of the fire-room force. There are no cinders, and the amount of smoke can be controlled. A considerable reduction in personnel is possible. The weight and space required for boilers is reduced: First by the reduction in heating surface required, and, second, by the shortening of fire-rooms. Consequent on the reduction in heating surface is a decrease in weight and cost of boilers. Coal and ash-handling gear is eliminated. This renders unnecessary the piercing of the hull for coal trunks and discharges from the ash expellers or ash ejectors. The stowage and handling of oil is much easier than of coal, and will result in a much cleaner ship, with consequent increase in time available for drills. The mechanical supply of fuel to the boilers gives a prompt and delicate control of the steam supply, permitting more sudden changes in speed than with coal, which is a tactical advantage. The nature of fuel oil permits utilisation of remote portions of the ship and of constricted space for its stowage.

These advantages have long been recognised by the Navy, and there have been experiments with liquid fuel dating back as far as 1867. All these experiments have confirmed the belief in the considerable military advantages which will accrue from its use; but until recently it has been impracticable to use it extensively on account of the uncertainty as to the adequacy of its supply and the sufficiency of its distribution among the seaports of the world. We are now assured, however, as regards the supply.

Since 1907 all U.S. torpedo-boat destroyers contracted for, of which there are 29, burn oil exclusively, and the battleships "Delaware," "North Dakota," "Florida," "Utah," "Wyoming," "Arkansas," "Texas," and "New York," contracted for during this period, are fitted to burn oil as auxiliary to coal, each of these vessels carrying about 400 tons of the liquid fuel, to be burned at full power after the coal fires become dirty, or when it becomes difficult to trim coal from the bunkers into the fire-rooms. In the case of these battleships the advantages of the oil have so appealed to the personnel that oil alone is burned to a great extent in port, and to some extent while cruising, although the installation of the oil-burning equipment did not contemplate these uses.

The "Nevada" and "Oklahoma," the two battle-ships which have recently been contracted for, will burn oil exclusively. This is perhaps the most radical development in naval engineering since the advent of the turbine. It has permitted in the case of these vessels a reduction in boiler weights, which has made possible the use of heavier armour than has hitherto been employed. The reduction in the length of boiler compartments has permitted the grouping of all boilers under one smoke pipe, which, of course, clears the upper deck considerably, and permits more extensive arcs of fire for the turrets.

Aside from the use of oil as fuel under steam boilers, it now seems probable that within comparatively few years oil used in internal-combustion engines will furnish the principal fuel for all naval vessels. This is in consequence of the recent remarkable development of heavy-oil engines of the Diesel type in Europe. Hitherto oil engines have not merited much consideration for large naval vessels on account of the limited power that could be developed in a single cylinder. An installation of any considerable power required a multiplicity of cylinders. Now, however, we are credibly informed that 1,000 h.p. has been developed in a cylinder about 33in. diam. with a 40in. stroke, at 150 revs. per minute, in a 2-cycle marine-type readily reversible engine. This engine has a speed control that is satisfactory, and an economy of fuel consumption probably twice that of a steam engine.

In the U.S. Navy, heavy-oil engines built or so far projected are limited to a number of submarine vessels and to mother ships for submarines. Gasoline is used as fuel for all of our earlier submarines and for a large number of small power boats carried by warships. Its use is likely to be discontinued entirely as soon as suitable heavy-oil motors for the small power boats are developed.

* Abstract of paper presented at the Eighth International Congress of Applied Chemistry.

PRESENTATION TO MR. HAROLD REDDAWAY.

To celebrate the coming-of-age of Mr. Harold Reddaway, the only son of Mr. Frank Reddaway, the founder, chairman, and managing director of Messrs. F. Reddaway & Co., Ltd., Pendleton, Manchester, the well-known firm of belting manufacturers, a social gathering of the employés of the firm was held on Christmas Eve at the Co-operative Hall, Pendleton. An interesting feature of the proceedings was the presentation, on behalf of the employés, of a valuable dressing case to Mr. Harold Reddaway, who, in acknowledging the gift, said he would regard it as one of his most treasured possessions, and it would recall to his mind the happy occasion that had brought about their meeting together that night. Mr. Frank Reddaway, in the course of a speech, said his son had passed through his college experiences, which were doubtless very pleasant and agreeable, and now he was coming right down to them in this smoky corner of the Empire, and would begin to learn the business, which he hoped his son would be able to manage and direct as successfully as he had done. He held that unless a man knew his own business thoroughly he could not direct it successfully or direct those who were connected with it. With that end in view, early in the New Year, his son would be amongst them, and he was sure he would do his utmost to learn quickly everything that was necessary in connection with the business. He was sure, from the way in which they had given expression to their feelings, that when his son came amongst them they would all do their best to help him on his way. Since the business was established 40 years ago it had made a great advance. They had very large mills in Russia, where they employed 1,500 or 1,600 people in the summer. In America they had a small mill which was so excellently managed that he had seldom need to visit it. Wherever he went amongst his workpeople, whether in Pendleton or in Russia, he felt that he was never received in a hostile spirit or with looks of envy, but always with a smile of welcome. It had been his aim and endeavour to win the confidence of all around him, and that could only be achieved by being absolutely just as between man and man. He was very proud to be with them on this occasion, and the manner in which the presentation had been evolved had afforded him especial satisfaction, as it was a presentation that had come solely from the workpeople themselves.

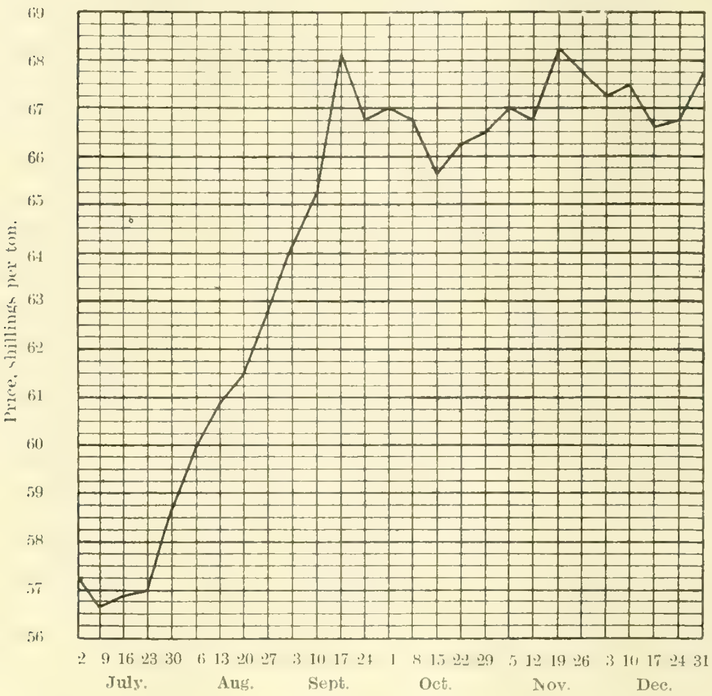
Novel German Ferry Boat.—An American Consular Report says an unusual type of ferry-boat has just been completed for the port of Hamburg, and as a sister ship is being constructed, it is evident that the authorities are satisfied with the type of vessel that has been developed. The essential feature of the new vessel is a movable deck with a lifting power sufficient to provide for an elevation of 16·4ft. with a load of six freight cars, three on each side. The vessel itself is of 470 tons gross measurement, and is 116·47ft. long, 50·85ft. in breadth, 12·46ft. deep. It has two triple-expansion engines of 640 i.h.p. The lifting of the deck is made possible by a high steel superstructure, on the top of which is the officers' bridge, from which point all the operations of loading, unloading, and navigation can be carried on. A ferry service of this character is now necessary because of the great extensions being made to the port of Hamburg. The berth in which the vessel enters and receives its load is completely enclosed, so that it is not influenced by the current of the river, or the movements of passing steamers.

INDUSTRIAL AND TRADE NOTES.

Cumberland Furnacemen's Wages. The quarterly ascertainment under the sliding scale operating in Cumberland shows that the average selling price of hematite iron warrants was 81s. 8d. per ton, compared with 76s. 9d. in the previous quarter. Cumberland furnacemen's wages are, therefore, increased by 6¼ per cent., and are 24½ per cent. higher than the corresponding quarter last year, or 52¼ per cent. above the standard.

Shipyard Combine. An arrangement has just been concluded between Messrs. Swan, Hunter, & Wigham Richardson, Ltd., shipbuilders and engineers, of Wallsend and Walker-on-Tyne, and Messrs. Barclay, Curle, & Co., Ltd., shipbuilders and engineers, of Whiteinch, Glasgow, whereby an exchange of shares is effected and a community of interests is ensured. The management of the respective companies will remain unchanged.

Prices per Ton of Cleveland Iron, July to December, 1912.



New L. & N.-W. Locomotives.—Orders have been received at Crewe Railway Works to build a large number of locomotives, which, when completed, will be the most powerful in the country. They have been designed especially to draw maximum loads at high speeds, and will be of the four cylinder type. The distribution of steam will be by a new piston valve. The engines will have ten wheels, of which the six drivers will be 6ft. 6in. diam. They will cost approximately £5,000 each.

Personal.—Sir William E. Smith, C.B., a director of naval construction to the Admiralty, has, we understand, joined the Board of Directors of Messrs. Armstrong, Whitworth, & Co., Ltd. Sir William has been up to the present year superintendent of construction accounts and contract work at the Admiralty, a position he held for ten years. Previously he had been an Admiralty naval constructor. He has also been an instructor in naval architecture at the R.N. College, Greenwich. He is a vice-president of the Institution of Naval Architects.

Tin-mining Areas in Nigeria.—The tin mining areas in Nigeria are to be systematically surveyed, and the Colonial Office states that no more exclusive licenses to prospect will be issued, and no more mining leases will be granted, until that survey is well advanced, except (1) in the case of applicants for exclusive licenses to prospect who have on or before October 16th already left for Nigeria, and to whom refusal to grant it would cause hardship; and (2) in the case of applicants for mining leases who already possess exclusive licenses to prospect which entitle them to mining leases.

The Japanese Mercantile Marine.—In 1911 the mercantile marine of Japan consisted of 31,600 vessels, of which 2,550 steamships are of an aggregate tonnage of 1,100,000; 6,400 sailing vessels and 22,650 junks. Compared with the previous year, this shows an increase in the number of 170 steam and 455 sailing vessels. Japan possesses two steamers of over 10,000 tons burden each, one of 9,500 tons, and six of between 8,000 and 9,000 tons. Twenty four lines of steamers receive subventions from the Government. The fleets of four of the most important of these lines represent a total tonnage of upwards of half a million.

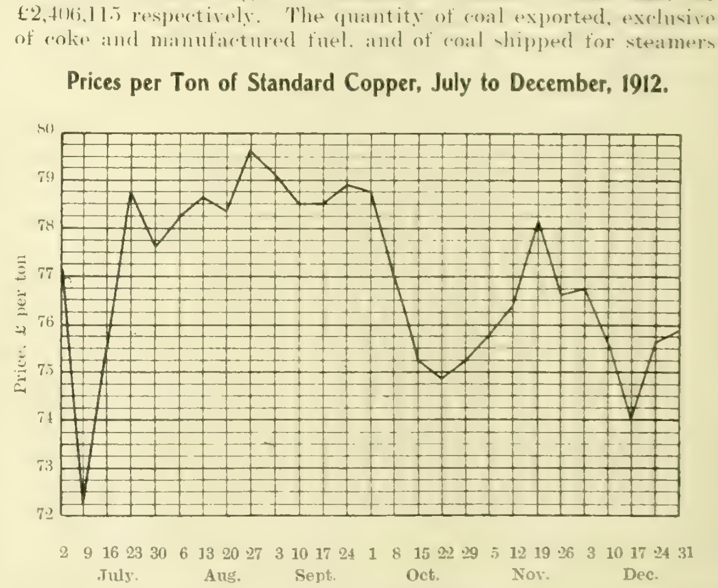
Floating Dock for the Argentine Navy.—The contract for a new floating dock for the Argentine Republic has been awarded to Messrs. Vickers, of Barrow-in-Furness. The dock, which will be double-sided, of the Clark & Standfields "box" type, having a length of 300ft., breadth 60ft., and a width at the entrance of 45ft., is intended for the accommodation of torpedo-boat destroyers and light craft generally up to 16ft. draught. The dock will have a lifting capacity of 1,500 tons. There will be complete and self contained pumping and electric lighting installations. The trials are to be carried out by the Argentine Naval Commission in England, and the dock delivered at Buenos Ayres within nine months.

The Science Museum: Advisory Council Appointed.—The President of the Board of Education announces he has appointed an Advisory Council for the Science Museum. The council will be asked to advise the Board on questions of principle and policy arising from time to time, and to make an annual report on their proceedings to the Board, together with any observations on the condition and needs of the museum which they may think fit to make. The first members of the council will be Sir Hugh Bell (chairman), Mr. R. Elliott Cooper, Dr. J. J. Dobbie, Mr. W. Duddell Mr. E. B. Ellington, Sir Maurice Fitzmaurice, Sir Archibald Geikie, Dr. R. T. Glazebrook, Sir Alfred Keogh, the Right Hon. Sir William Mather, Sir John Murray, Sir William Ramsey, the Right Hon. Sir Henry E. Roscoe, and Sir William H. White. The secretary will be Captain H. G. Lyons, of the Science Museum.

Birmingham's Electricity Supply.—The Electric Supply Committee of the Birmingham City Council, accompanied by their engineer and secretary, will shortly visit London, Newcastle-on-Tyne, Glasgow, and Liverpool to inspect the most modern power stations before finally deciding upon the details of the equipment of the new Nechells depôt, the erection of which was recently resolved upon. It will be remembered that at their meeting on December 12th the committee, subject to the approval of the City Council, decided upon their scheme for the extension of the electric supply undertaking necessitated by the steady increase in the output of electricity. The scheme provides for the construction of a new electricity generating station on the land acquired from the Drainage Board at Nechells. The idea is eventually to erect buildings and plant for the production of 100,000 kw., but at the outset the committee will only erect buildings and lay down plant for 25,000 kw., and the cost of this portion of the work and equipment is estimated at £250,000.

British Coal Output.—Part III. of the General Report of Mines and Quarries for 1911, dealing with output, and issued by the Home Office on the 3rd inst., shows that the total value of minerals raised for the year amounted to £124,579,313, an increase of nearly two and a half millions as compared with the previous year. The total output of coal was 271,891,899 tons, and the value £110,783,682, showing an increase of 7,458,871 tons and of £2,406,115 respectively. The quantity of coal exported, exclusive of coke and manufactured fuel, and of coal shipped for steamers engaged in foreign trade, was 64,599,266 tons, or two and a half million tons more than in 1910. France received over ten and a quarter million tons, Italy nearly nine and a quarter millions, Germany nearly nine millions, Sweden nearly four millions. Russia nearly three, Argentine over three and a quarter, Egypt and Spain over three, Denmark over three-quarters of a million, and the Netherlands nearly two and a quarter millions. The total quantity of coal which left the country was over 87 million tons,

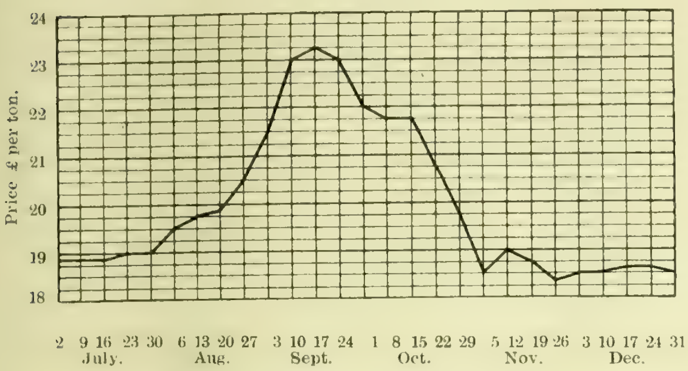
Prices per Ton of Standard Copper, July to December, 1912.



as against 84½ millions. The amount of coal remaining for home consumption was 184,810,517 tons, or 4,079 tons per head of the population.

A Large Hoisting Cable.—There was recently tested in the laboratory at the Lehigh University what is claimed to be the largest hoisting cable ever constructed. It was manufactured by J. A. Roeblings Sons, & Co., to the order of the Spanish-American Iron Company, for use in a mine in Cuba. During the test it took a pull of 364 tons to break the cable, which consists of six strands, each of 19 wires, twisted around an independent wire rope centre,

Prices per Ton of English Lead, July to December, 1912.

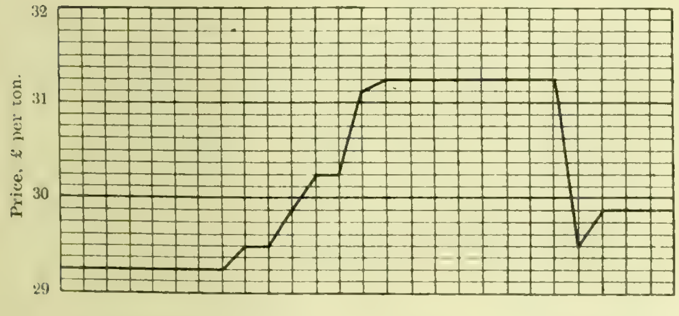


this centre having six strands of 19 wires each, twisted around a hemp core. The finished cable was 7,810ft. long, and weighed 125,360lbs. Cars with a capacity of 100,000lbs. of ore are lowered by means of this cable down an incline plane 5,800ft. long.

Time Required to Build Dreadnoughts.—According to a printed reply by Mr. Churchill to Mr. Higham, the time occupied in building ships of the Dreadnought type that have already been completed in Great Britain has varied from one year and five months to three years and four months from the date of ordering. In the case of Germany the times elapsing before the completion of trials have varied from two years and nine months to three years and six months.

Swiss Hydro-Electric Power Developments.—The past 15 years have witnessed a remarkable advance in hydro-electric power development in Switzerland, says the American Vice-Consul at Zurich in a recent report, and stations for the production of electrical energy have sprung into existence in all parts of the country, following the rapidly-increasing use of electricity and the demand for cheaper power. In 1911 there were 783 electric power plants in operation in Switzerland that furnished central station service; in addition there were many small isolated plants not included in these remarks. Of the 783 plants referred to, 473 belonged to corporations that did not generate electrical energy, but merely bought from larger plants and resold to retail customers. Of the 310 generating stations, 233 were wholly or nearly wholly hydro-electric plants and only 77 were steam or gas-driven plants, all of these being small. Several of the hydro-electric stations have

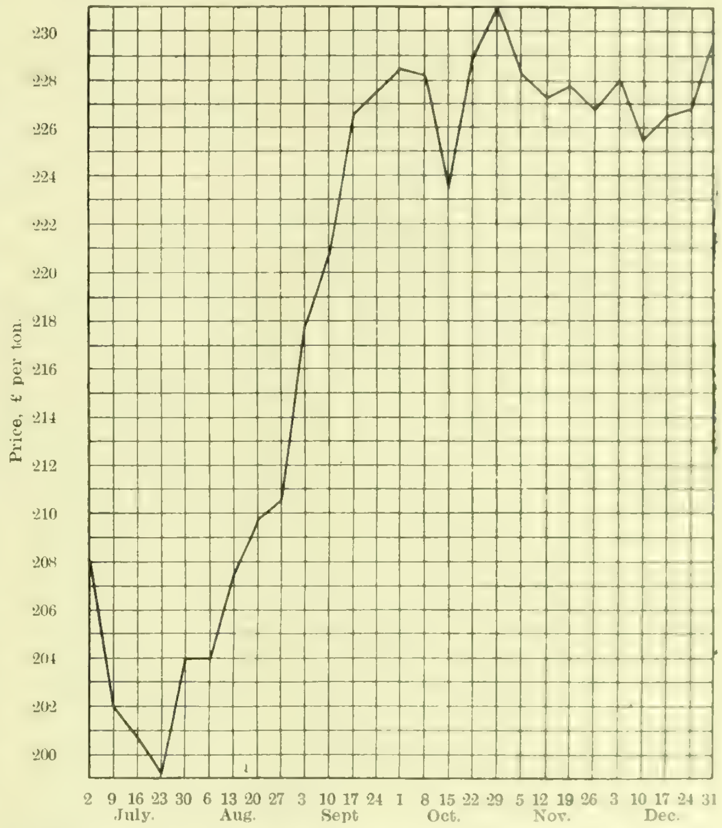
Prices per Ton of Silesian Zinc Sheets, July to December, 1912.



steam auxiliaries, however, to provide for low-flow periods in rivers fed from glacial sources. In the fiscal year 1910-1911, 108 electric power plants were completed and placed in operation. On account of the importance and great value of cheap electric power to the Swiss people, the Swiss Federal Government has imposed many restrictions to its exportation to neighbouring countries. The Government holds no monopoly, however, over its rivers and streams for power purposes. It is estimated that Swiss waters are capable of furnishing energy to the extent of 2,000,000 h.p., and of this amount 500,000 h.p. to 700,000 h.p. is now harnessed and in actual use. The total length of overhead transmission line was over 1,600 miles last year.

Canadian Method of Preventing Strikes.—In a recent paper by Mr. W. L. M. King, the author referred to the method adopted in Canada for the prevention of strikes. The Canadian Industrial Disputes Investigation Act, passed in 1907, was, he said, conceived primarily to protect the public against a repetition of a fuel famine caused by a strike of coal miners. In providing, however, machinery at the expense of the state to aid in the prevention of strikes and lockouts, the statute was made to include mines, railways, and street railways, steamships, telegraph and telephone lines, gas, electric light, water and power works. Before a strike or lockout can take place the parties aggrieved must apply to the Government for a Board of Investigation, each party to elect a representative, and these two a chairman, or, failing their agreement, the Government to appoint a chairman. The Board is expected to try conciliation, and, that failing a settlement, to proceed formally. Its findings, failing a settlement, become the official utterance through which public opinion is shaped and brought to bear. If the parties reject the finding they may strike or lockout. In other words, compulsory arbitration, as understood

Prices per Ton of Block Tin, July to December, 1912.



in Australasia, was not viewed with favour, and was not made a part of the Canadian plan. What we have is compulsory investigation and compulsory publicity. In practice no compulsion has proved necessary, except that of public opinion. In the five and a half years there have been 132 applications for boards, of which 53 were in railways, 40 in coal mining, and the rest in several other occupations. Out of the 132, strikes were averted in all save 15. There have been only four railway strikes. Prior to the Act not a year passed without a street railway strike; since the Act, there has been just one in all Canada. Hence, Canada has enjoyed for nearly six years all but complete immunity from lockouts and strikes on all her important agencies of transportation and communication. To the public the Act has been of real service, and is appreciated. The railway companies, which, at the outset, were inclined to view with suspicion, if not alarm, the wide power of a board to search their records and question their officials, now without exception endorse it.

Hydraulic Stowage in Mines.—The recent report on mines and quarries states that hydraulic stowage has for the first time been tried in this country. This method is increasing in Westphalia, and it is considered that the majority of coal mines will be obliged to adopt the system. Where sand can be used as the material the method is cheap, and it is maintained that expenses for pit timber are reduced and the coal output increased.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Production of motive power. Aspinall. 22912.
Internal combustion engines. Robb, Welch, & Banner Motors, Ltd. 25379.
Rotary gas engines. Berliner. 25142.
Locomotive boilers. Marks. 28019.
Apparatus for purifying water. Paterson. 28179.
Coating of steel or wrought iron with chilled cast iron. Davies. 28181.
Flying machines. Stephen. 28266.
Centrifugal pumps. Taylor & Weil. 28326.
Motor propelled road vehicles. Arter & Arter. 28327.
Driving mechanism for power driven vehicles. Mirkov. 28363.
Vaporisers for internal-combustion engines. Houghton. 28393.
Clutches. Jardine & Watchorn. 28415.
Means of driving grinding wheels. Wolseley Sheep Shearing Machine Company, and Walton. 28435.
Carburetters for internal combustion engines. Grove. 28551.
Smoke consuming devices for furnaces. Lupton & Armitage. 28627.
Hoisting or winding gear for arc lamps. Worsley. 28668.
Carburetters. Williams. 28716.
Two-cycle internal-combustion engines. Nielsen & Nielsen. 28866.
Dynamometer. Stott. 28884.
Hydraulic safety gear for presses. Thos. C. Fawcett, Ltd., and Fawcett. 28891.
Hydraulic lifts and cranes. R. Waygood & Co., and Carey. 29275.

1912.

Rotary pumps. Pearson. 240.
Pipe couplings. Molien & British Mannesman Tube Company. 1666.
Transmitting power from windmills. Jack. 1903.
Compensating luffing cranes. Sir W. G. Armstrong, Whitworth, and Co., and Right. 2758.
Two-stroke cycle internal-combustion engine. Lancaster. 2905.
Expanding pulleys for light motor vehicles. Cairns. 3383.
Distributing gear for internal combustion engines. Lafitte. 3851.
Two-stroke internal-combustion engines. Samain. 4225.
Internal combustion engines. Peel. 4443.
Couplings for colliery trams or corves. Hughes. 4560.
Furnaces. Atherton. 4578.
Steam superheating tubes for locomotive boilers. Howell. 4640.
Point levers for use on railways. Vellère. 4981.
Flues and smoke-tubes for steam boilers. Hounjet. 5419.
Method of extracting vanadium from ores. Saklatwalla. 6118.
Internal-combustion engines. Hall. 6389.
Piston rings. Patrick. 6973.
Hydraulically moved circular saws for cutting metals. Gelsenkirchener Bergwerkes Akt. Ges. 7436.
Centrifugal compressors. British Thomson-Houston Company. 8245.
Starting systems for internal-combustion engines. Beil. 9139.
Locking devices for nuts. Bolton. 9408.
Axle-boxes and bearings for railway vehicles. Parkes. 9844.
Furnaces for the treatment of metalliferous ores, coking coal, &c. Benjamin. 9986.
Automatic-block signalling systems for railways. White (Carson). 10208.
Non continuous girder for swing bridges. Orrell. 10900.
Valve mechanism for four stroke internal-combustion engines. Guitton. 11042.
Tube casting moulds. Hayes. 11186.
Differential or balance gearing. Cake. 11320
Pulley blocks. Parkinson. 13664.
Air brakes. Christensen. 13794.
Motor vehicles. West. 14106.
Railway car couplings. Sole, Farley, & Mackle. 14861.
Pistons for revolving cylinder engines. Berliner. 15068.
Lubrication of explosive engines. Mead. 15597.
Rotary explosion engines. Coanda. 15855.
Power transmission mechanism. Soc. Anon. des Automobiles Delaunay Belleville. 15863.
Power machine plant. Allgemeine Elektricitats Ges. 16517.
Auxiliary air valves for carburetters of internal combustion engines. Stewart. 16672.
Process for forming a protective coating on metals. Tonet. 17676.
Internal combustion turbine engine. Pope & Robertson. 18415.
Arrangement of nozzles for steam or gas turbines. Akt.-Ges. Brown, Boveri, et Cie. 20060.
Mechanism for transforming rotary movement into reciprocating movement. Albert. 20502.
Slewing cranes. Imray. 23762.
Operating mechanism of single chain grabs. Burgdorf. 24014.

ELECTRICAL, 1911.

Electric conductors. Kallmann. 28159.
Voltage regulation of direct current generators. Akt. Ges. Brown, Boveri, & Co. 28486.
Storage battery separators. Taylor. 28858 and 28859.

1912.

Terminals such as contacts and electrodes in electrical apparatus. British Thomson Houston Company. 535.
Wireless telegraph receiving apparatus. Marconi's Wireless Telegraph Company, and Round. 3055.
Electric distribution systems. British Thomson Houston Company, Taylor, Whittaker, and Sporborg. 3532.
Dynamos. British Thomson Houston Company, and Garton. 4529.
Turbine dynamo plant. Warwick Machinery Company (1908). 7497.
Vapour electric devices. British Thomson-Houston Company. 7775.
Terminals for electric batteries. Lucas & Jackson. 9278.
Speed regulation of asynchronous motors. Bergmann Elektricitäts Werke Akt.-Ges. 12134.
Excess consumption meter for electric circuits. Schuppisser. 13602.
Combination electric lamp bulb and diffuser. Frenot. 13796.
Electric switches. Merriam. 14752.
Telephones. Ramdohr. 16241.
Production and wireless transmission of electrical oscillations. Heinicke & Jasper. 18632.
Igniting current distributors for internal combustion motors Siemens & Halske Akt.-Ges. 19069.
Electric wire terminal plugs. Mowrer. 23564.
Plug for electrical plug contacts. Stotz & Compagnie Elektricitäts Ges. 23877.
Devices for adjusting the length of the spark gaps between electrodes. Imray. 26457.

METAL QUOTATIONS.

TUESDAY, JANUARY 7TH.

Aluminium ingot	95/- per cwt.
„ wire, according to sizes, &c. ......from	112/- „
„ sheets „ „ ...... „	120/- „
Antimony ....£38/-/- to	£40/-/- per ton.
Brass, rolled	9d. per lb.
„ tubes (brazed)	$10\frac{7}{8}$d.
„ „ (solid drawn)	$9\frac{1}{2}$d.
„ „ wire	9d.
Copper, Standard	£76/2/6 per ton.
Iron, Cleveland	67/9 „
„ Scotch	73/9 „
Lead, English	£18/10/- „
„ Foreign (soft)	£17/13/9 „
Mica (in original cases), small	6d. to 3/- per lb.
„ „ „ medium	3/6 to 6/- „
„ „ „ large	7/6 to 11/- „
Quicksilver	£7/15/6 per bottle
Silver	$29\frac{3}{8}$d. per oz.
Spelter	£26/7/6 per ton.
Tin, block	£229/-/- „
Tin plates	15/9 „
Zinc sheets (Silesian)	£29/17/6 „
„ (Stettin; Vieille Montagne)	£30/5/- „

Water Transportation in the United States.—A report by Mr. Luther Conant, the Federal Commissioner of Corporations, on water transportation, says that railway companies and steamship combinations control the regular domestic steamship lines of the United States, and have destroyed much competition. The water lines on the Atlantic and Gulf coasts, he says, are largely auxiliaries and subsidiaries of the railways. The railways are declared to own important through passenger and package freight lines to the Great Lakes, while the important hard coal fleets on the Atlantic coasts are reported as being owned by a few great anthracite railways. Railways also control 90 per cent. of the mileage of private canals, and have caused many such waterways to be abandoned. The Commissioner concludes with a recommendation for an extension of the Federal regulation of joint rail and water traffic.

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Edited by
WILLIAM H. FOWLER,
Wh. Sc., M.Inst.C.E.

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Water Softening and Purification: Some Recent Developments.

THE question of water softening and purification is one that is often presented in some form or another to engineers, manufacturers, and local authorities. When used for boiler purposes the presence of certain dissolved salts seriously affects its suitability, sometimes on account of its corrosive properties, but more frequently on account of the scale or deposit which is formed and which in some cases may be troublesome to remove and involves periodic stoppages for the purpose, or in others leads to serious risk of overheating of the plates owing to interference with the transmission of heat. To many manufacturers a copious supply of pure soft water is a great desideratum of their business, since the presence of dissolved lime salts, as in the bleaching and dyeing trades, involves a serious expense for soap owing to the hardening effect which such impurities have upon the water, while for a similar reason governing authorities have frequently to treat the whole of the available supply.

When impurities consist solely of suspended matter, filtration is a comparatively easy remedy, but in the majority of cases this does not remove all the objectionable qualities. The presence of carbonates or sulphates of lime or magnesia causes "temporary" or "permanent" hardness, according as the hardness is, or is not, removed by boiling. "Temporary" hardness is due to the presence of the carbonates, while the presence of chlorides, nitrates, or sulphates (generally the latter) constitutes what is known as "permanent" hardness. The two kinds of hardness may exist together in the same water and each requires different treatment. In the early days of steam a wonderful variety of remedies were tried for scale and deposit troubles in boilers, from bags of potatoes to carcases of pigs, or doses of treacle, sawdust, or glue. Although relief was found in some cases from these nostrums, general experience was disappointing, and it came to be recognised that rational chemical treatment, based on a scientific analysis of the water to ascertain the nature of its

impurities, was the only satisfactory remedy, though there are some steam users who still seek relief for their troubles in what are little better than quack remedies.

It was Cavendish who discovered, so far back as 1766, that the carbonates could be precipitated by treatment with lime, though a long period elapsed before the discovery was put to much practical use, because these salts may be precipitated by heating in the boiler, and few boiler users recognised the desirability of treatment outside it until higher pressures, higher rates of combustion, and general boiler economy compelled greater attention to the subject, and led to a gradual recognition of the fact that mechanical contrivances and patent nostrums which deal only with troubles imported into the boiler are a poor substitute for independent, well designed water-softening apparatus. The bulk of the impurities, viz., carbonates and sulphates, can be cheaply and practically dealt with by lime or caustic soda, as was first shown by Porter and Clark some 40 odd years ago. The disadvantage of their apparatus was that it was cumbrous and sometimes unsatisfactory owing to the length of time required in some cases for the separation of the precipitated impurities, but this treatment still forms the basis of the water-softening plants of to-day, though great improvements have been effected in the designs of the apparatus with a view to diminishing their size and increasing their speed of separation of impurities.

During the last few years attention has been directed to one or two new suggestions for dealing with the hardening impurities of water. In our issue for March 10th, 1911,* we drew attention to the extraordinary effects that were claimed to be produced by merely allowing water to flow over a sheet of aluminium, and pointed out the utter lack of reliable evidence to justify the claims made, and we have not since seen any records of tests or evidence that warrant us in modifying the opinions we then expressed regarding this system.

Another system of water softening, however, which, in this country at all events, is comparatively new, and at present has here only received limited application, deserves attention on account of its ingenuity and potentialities. We refer to what is termed the "Permutit" water-softening process. The process, like many other chemical inventions, is due to the ingenuity of a German, though its origin lies in certain facts that have been familiar to agricultural chemists for over 60 years, viz., that certain minerals in soils containing silicates of aluminium and soda, and termed "zeolites," possess the property of exchanging their alkaline base for a calcium equivalent, without being in the ordinary sense soluble. The action has an important bearing on the nourishing of plants, and its discovery led to a good deal of investigation subsequently from this point of view. This does not, however, concern us here, though it eventually led Dr. Gans, of Berlin, to conduct a research that culminated in the artificial preparation of zeolites, capable of many industrial uses. These compounds, on account of their special capacity to effect chemical change, he terms "permutits" ("exchangers"). The one most generally used for water purification, permutit of sodium, is a double silicate of aluminium and sodium. Its chemical formula is somewhat long ($2SiO_2\,Al_2O_3, Na_2O, 6H_2O$), but this need not trouble the general reader, since an intelligent idea of its action may be gathered without special chemical knowledge. Briefly, and without going into details, the process consists in slowly passing the water to be purified through a bed of "permutit," with the result that the carbonates or sulphates of lime or magnesia with which the water may be impregnated become converted into carbonates or sulphates of sodium, which are highly soluble, and may be passed into the boiler direct without fear of forming scale or deposit. This action continues until all the soda base of the "permutit" is exchanged for a calcium base. At this stage the "permutit" becomes inert as regards its influence upon the feed water, but and herein lies the ingenuity of the process—the "permutit" may be again regenerated by passing through the bed a solution of common salt, or sodium chloride, the calcium in the "permutit" being now exchanged for the sodium in the salt solution, and the substance brought back to its original condition, the calcium during this process being of course rejected. No filtration is necessary in the process, nor is any fresh supply of the "permutit" required beyond that for the minute percentage which is carried away mechanically in the washing processes. The only chemical material required is the supply of salt for the regenerating operation. The manipulation of the apparatus involves no more than the opening and closing of certain taps at stated periods, and its supervision can be undertaken by an ordinary workman with very little instruction.

The relative advantages of the "permutit" process as compared with the soda-lime process depend on circumstances. In the latter, for each degree of "temporary hardness," (*i.e.* one part of hardening salt per 100,000 parts of water), about 2·5ozs. of lime per 1,000 gallons is required, and for each degree of "permanent hardness" a similar quantity of soda. There is a material difference in the cost of these two re-agents, and speaking roughly it may be said that the removal of a degree of "permanent hardness" by the soda-lime process costs 3½ to 4 times as much as the removal of a degree of "temporary hardness." There is one disadvantage of this process, however, when softened water is used for washing purposes, namely, that it is not, practically speaking, possible to remove all the hardness from the water, and 2 to 3 degrees nearly always remain. For boiler purposes this may be negligible, but when it is borne in mind that 2lbs. of soap are required to remove one degree of hardness from 1,000 galls. of water, it is easy to see that when water is used on a large scale, as in wool washing and similar industries, a hardness of 3 degrees may entail a serious daily loss from the use of soap. The advantage of the "permutit" system lies in the fact that the process permits of complete removal of the hardness, but, unlike the lime-soda process, "temporary hardness" is the more costly to remove, and entails about 40 per cent. greater expenditure in salt solution than the "permanent hardness." Although salt is a cheap renovating material, its cost does impose limits in the competition between the two processes, and, as a matter of fact, it is hardly advantageous to apply the "permutit" process if the water possesses more than about 14 degrees of hardness. In many cases, of course, the degree of hardness is greatly in excess of this, and it is easy to see that it may in some circumstances pay to remove the major part of the hardness by means of the soda lime process and to finish the softening by means of "Permutit." The presence of sodium carbonate or sodium sulphate, although they are very soluble, may cause trouble if they are present in excess, and hence, whatever softening process is adopted a certain amount of blowing off in boilers is desirable where there is a risk of this, as otherwise trouble is liable to arise with brass fittings or through slight weeping and incrustation at the seams of rivets below the water level. We are informed, however, that in this respect "Permutit" shows to advantage, since the complete softening it effects

* See "Mechanical Engineer" p. 279, Vol. XXVII.

appears to diminish, at anyrate, the trouble from weeping at the seams, probably owing to the absence of the carbonates which are thrown down by secondary deposition when the soda lime process is adopted. The filtration of these, it is well known, is very troublesome and the methods of effecting it constitute to a large extent the differences in detail in the various water-softening apparatus that are in use. We have, however, seen some interesting demonstrations which show that this well-known trouble may be overcome in a remarkably cheap and simple way. We are not at liberty to disclose the details of this discovery, but as it may before long be made public it is interesting to know that by the addition of a harmless reagent in very minute quantity the precipitation of the carbonates can be effected in an extraordinarily rapid way, and by so doing materially improve the efficiency of ordinary water-softening plants.

DANGERS OF PHOSPHORUS AND SODIUM.

BY C. VICKERS.

PHOSPHORUS is considered the most dangerous chemical used in foundry operations, on account of its liability to spontaneous combustion, and there is little doubt but that it has been responsible for many mysterious fires that have occurred in brass foundries. The exercise of a little common sense, however, is all that is necessary to guard against danger from this source. Phosphorus must be kept stored under water at all times, otherwise, at ordinary shop temperatures, it will inflame in about seven minutes. The fact that water evaporates should never be lost sight of, also that iron containers are liable to rust and leak, leaving the phosphorus exposed to the atmosphere. The best plan is to use two receptacles, one inside of the other, for the storage of this dangerous chemical. The outer vessel should be a strong keg and the inside container may be the original can in which the phosphorus was received. The keg should be filled with water, so that the can is totally immersed. The keg should be stored where it is always visible, and either should be left uncovered or an employé should be held responsible for the maintenance of the water level. In the event of the keg leaking, water would remain in the can and would preserve the phosphorus until the condition of the keg was observed.

Regarding the handling of the phosphorus after it has been removed from the water for addition to the metal, much has been written, which may be summed up in the statement that vigilance and care are the price of safety. It is not necessary, however, in these days of rich alloys to use the yellow variety of phosphorus, as phosphor-copper and phosphor-tin afford a much more convenient means of using phosphorus, in all ordinary foundry operations.

Another dangerous element sometimes used in brass foundries, is metallic sodium. This metal is the direct opposite of phosphorus as regards treatment in storage, as it must be kept away from water, contact with it causing it to inflame, consequently, it should be stored in a dry place and should be kept covered to exclude moisture. It is in some cases stored under naphtha, but this is not necessary, as when exposed to the air the surface of the cut metal rapidly oxidises and becomes covered with a protective coating of caustic soda. Its addition to bronze is more difficult than phosphorus, as the latter, when tossed on to the surface of the molten metal, has such an affinity for the latter that it is to a large extent absorbed. This may be observed easily by taking two pieces of phosphorus of equal size and igniting one on the floor, while the other is tossed on to the surface of molten metal.

The piece on the floor will continue to burn long after the piece added to the metal has entirely vanished, thus showing that it has been absorbed largely by the metal. Sodium, however, will float on the metal and burn away without producing any useful effect, and the copper, when cast, will be just as spongy as if never treated, because the sodium has not entered the metal. It is not as convenient, therefore, as phosphorus for foundry use, although it is an excellent deoxidiser, and will produce a metal in some respects superior to phosphor-bronze when the sodium is properly added. It oxidises out of the metal at each remelting to such an extent that fresh additions have to be made every time the metal is remelted.

Metallic sodium is used in the manufacture of aluminium and is sometimes shipped in large quantities to be used for that purpose. When carried by water the danger that may arise from its peculiar affinity for that element, and the necessity for its enclosure in strong, water-tight containers is illustrated by the loss of the steamer "Hardy" in December of last year.—"The Foundry."

THE CORROSION OF AUTOMOBILE RADIATORS.

NEARLY all automobile radiators are now made of brass, and while satisfactory as far as heat conductivity and durability are concerned, there is always more or less difficulty experienced by makers on account of corrosion occurring in the winter. This is the time of year when one would expect less corrosion to occur on account of the fact that chemical action is retarded by the cold. The fact is, however, that such corrosion is not produced by any defect in the radiator but in the solutions used in them. It is necessary, in order to prevent the freezing of the water in the radiator and engine jackets of an automobile during the winter, to use some liquid in them which will not freeze at the temperature of the coldest winter night. Drawing off the water has been found impracticable. It is in the use of this solution that the difficulty is experienced, although a few automobile owners know of the fact, and it is finally laid at the door of the radiator manufacturer who, in turn, may attempt to force it upon the maker of the brass sheet.

There are, says "The Brass World," many so-called "anti-freezing" solutions which, as far as their freedom from freezing is concerned, are quite satisfactory, but when it comes to the corrosion of the radiator are not. Calcium chloride, common salt, and similar substances are exceptionally bad and attack the brass rapidly. Glycerine is quite extensively employed in connection with alcohol, and is not to be recommended as, unless pure, the glycerine decomposes, forming compounds which attack the brass. Common glycerine is not suitable and pure glycerine is quite expensive. The glycerine mixtures, in addition to attacking the brass to a greater or less extent, are not favoured on account of their action on the rubber connections, and their sticky nature. Wood alcohol is not attended with satisfaction, when mixed with water in the proportion needed for the prevention of freezing, as it contains many foreign substances which have an injurious action upon the brass. In addition, wood alcohol, in presence of the heat and air, generates formic acid which, of course, attacks brass readily.

The best material for use in automobile radiators is grain alcohol (ethyl-alcohol) and by varying the proportions of water and alcohol any desired freezing temperature may be obtained. For example, 20 per cent. alcohol and 80 per cent. water freezes at about 10° above zero. A mixture of 30 per cent. alcohol and 70 per cent. water freezes at about 5° below zero. If the mixture is made of 40 per cent. alcohol and 60 per cent. water it will not freeze above 20° below zero, while 50 per cent. alcohol and 50 per cent. water freezes at about 35° below zero. De-natured alcohol can be used with equally as good results as the pure grain alcohol and is very much cheaper.

The Smoke Problem in Manchester.—An important step towards the solution of the smoke problem was taken by the City Council of Manchester on the 8th inst., when it unanimously decided to establish an Air Pollution Advisory Board, which will investigate and report upon the causes of the smoke evil and the best means of curing or minimising it. It is to include representatives of the chief committees of the Corporation and experts from outside. It will be the first official body of the kind in the country. An analysis of a mixture of Manchester soot made by Dr. Knecht, of the Manchester School of Technology, showed that it comprised ammonium sulphate, 10·7 per cent.; mineral matter (ash), 19·6 per cent.; acid constituents, 10·9 per cent.; benzine extract (hydrocarbons), 13·0 per cent.; difference (probably carbon), 45·8 per cent.

LARGE TURBO UNITS.*

BY J. P. CHITTENDEN.

(*Concluded from page 27*).

Reaction Type. — Taking the simple types of machines, perhaps the best known is that of the "Parsons" or reaction turbine, which has been in commercial use for nearly 28 years, during which time some hundreds of machines have been built, both on the single and double-cylinder principle. Of the former system, the section in Fig. 5 shows a good example of the general design of a single-cylinder machine of large output, and differs only slightly from the original Parsons design—the main difference being the arrangement of steam balance pistons, and the method of governing.

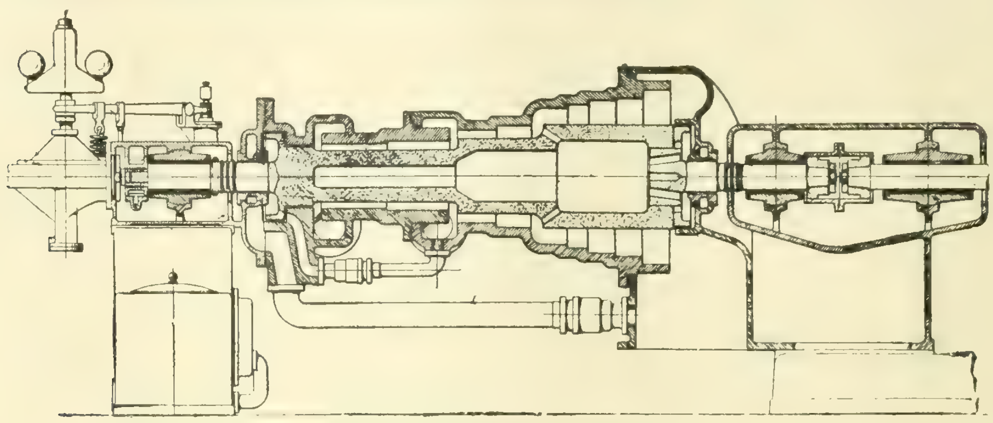


FIG. 5. PLAIN REACTION TURBINE.

The rotor and steam end shaft are made from one forging—the exhaust end being separate, and held in place by means of T-headed bolts. The rotor consists of three steps or stages in the proportion of $1 : \sqrt{2} : 2$. On this rotor are mounted 65 rows of reaction blading, divided up into 35, 15, and 15 rows respectively. The blading is carried in foundation rings, built up in half-segments complete with shrouding; the segments are then secured in grooves turned in the casing and rotor by means of caulking strips (Fig. 6). This method differs slightly from the usual reaction blade fixing, where separate blades and distance pieces are employed.

The casing, or turbine body, is of cast iron, and has nine increasing diameters to allow for an even expansion of steam through the turbine. The steam thrust, due to varying pressure throughout the turbine, is balanced by means of three labyrinth pistons, which are so arranged as to give perfect steam balance at all loads, the thrust block at the steam end only being used to set the position of the rotor relative to the casing. The governor gear consists of a double-beat throttle valve direct coupled to the main governor by a lever with a fixed fulcrum, and is arranged to control all loads up to 25 per cent. overload by means of throttling; loads beyond this are obtained by opening up by-pass valves.

Two-cylinder Type, Pure Reaction.—An excellent example of the 2-cylinder type of pure reaction machine is that of one of the six sets installed at Lots Road Station some few years ago by Messrs. C. A. Parsons & Co. As previously explained, this type consists of two separate casings and rotors, forming high and low-pressure portions. The normal rating of this machine is 6,000 kw. with 185lbs. square inch pressure, with superheat of 140° Fah. and 28in. vacuum, under which conditions a consumption of 14·01bs. per kilowatt was obtained.

The general construction is similar to that of a single-cylinder machine, with the exception of the high-pressure rotor, which is one complete forging. The governor gear is of the steam relay type which is standard for all Messrs. Parsons' machines, and differs from the ordinary relay system in that a floating lever is not used. This gear consists of a lever with a fixed fulcrum, to which is coupled on one end the main governor sleeve, and at the other the piston valve controlling the pressure on the under-side of the relay piston of the main throttle valve. This piston is not coupled to the governor lever, but is held down by a spring on the top of the piston, which keeps the main throttle on its seat. Steam is admitted to the under-side of this piston, so that when the speed of the set falls the piston valve closes and an excess pressure takes place on the under-side of the piston, which lifts the main throttle valve off its seat and allows more steam to enter the turbine. On the speed of the turbine rising an opposite action takes place, and the spring returns the throttle valve to its seat.

In Table I., Nos. 1 to 7, are given various steam consumptions and efficiencies obtained with the pure reaction type turbine.

Impulse and Reaction Type.—The impulse and reaction type, perhaps better known as the "disc and drum" turbine, is illustrated in Fig. 7, which is that of a 3,000 kw. at 3,000 revs. per minute. As will be noticed from this, the turbine is a combination of a 2-row Curtis disc, and the low-pressure portion of a reaction machine. This arrangement has, like all other compound types, the great advantage of low working pressures and temperatures in the turbine proper, and that there are no glands, &c., subject to high-pressure steam and consequent heavy leakage losses. The steam is expanded from initial to atmospheric pressure in the nozzles, and after having given up part of its kinetic energy in the disc, the steam is gradually expanded from this pressure through the reaction blading until the final or exhaust pressure is reached. The general design of the low-pressure end differs in no way from standard reaction practice, and has the usual balance piston and arrangement of thrust adjustment. The high-pressure disc is fitted with two rows of impulse blading, with a normal blade speed of 560ft. per second. These blades are made from drawn bronze section, cut to length, and milled to form the dove-tail root and pip for shrouding. The reaction end consists of 36 rows of fixed and moving blades which are attached to body and rotor as shown in Fig. 6.

With regard to the lower-speed machines, two drums of reaction blading are employed, so as to keep the diameter of the impulse disc within reasonable limits the steam pressure at the beginning of the reaction portion being increased to suit these conditions. A machine of this type is shown in Fig. 8, which is that of an 8,000 kw. turbine at 750 revs. per minute, working with 180lbs. B.P. 180° superheat and 28in. vacuum, and capable of carrying a continuous overload of 12,000 kw. by means of nozzle adjustment. The turbine is designed to suit a four-bearing arrangement, and fitted with a flexible coupling between it and the generator

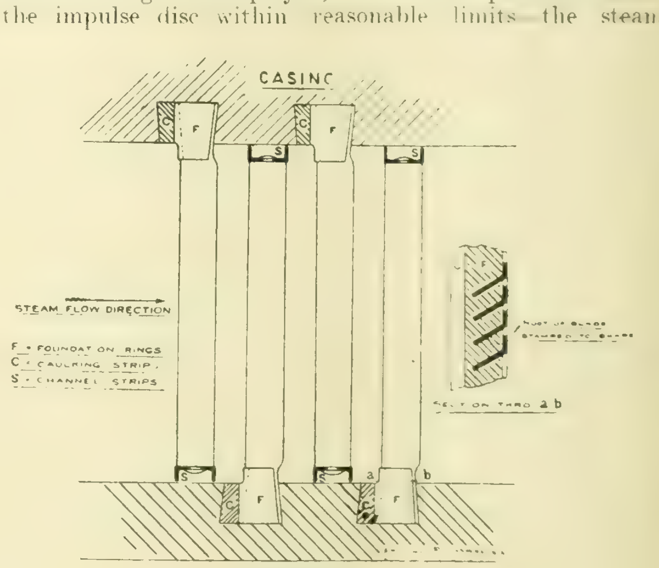


FIG. 6.—WILLANS-PARSON'S REACTION BLADING.

* Abstract of paper read before the Rugby Engineering Society, Jan. 7, 1913

bearings. Particulars of test results of this type of machine are given in Table I., Nos. 20-23.

Zoelly Type.—A machine constructed on the pure Zoelly principle was built by Messrs. Howden & Co., Glasgow, for the Manchester Corporation, test results of which are given in Table I., No. 12. The machine consists of 17 simple velocity wheels, 11 of which form the high-pressure and six the low-pressure end, these wheels carrying the standard type Zoelly impulse blades, the material being 5 per cent. nickel steel. In this type of machine there is no balancing arrangement, as the expansion of the steam takes place entirely in the fixed blades. The pressures each side of the discs are equal, and any slight out of balance is taken up by the thrust block. The governor is oil relay operated, the oil supply being taken from a small gear-driven pump working at a pressure of 80lbs. per square inch. Particulars of the test results obtained with this type of machine are shown in Table I., Nos. 12-17.

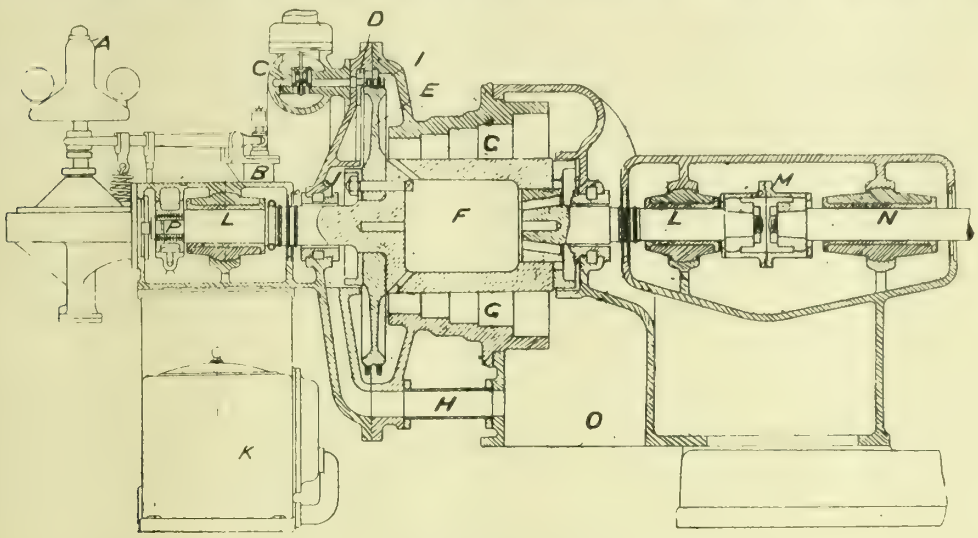


FIG. 7.—3,000 KW., 3,000 R.P.M., DISC AND DRUM TURBINE.

Curtis-Rateau Type.—In Fig. 9 is shown a machine combining the Curtis and Rateau principles, and is similar in design to those installed at Clyde Valley and Bristol by the British Westinghouse Company, Manchester, test results of which are given in Table I., Nos. 25 and 27 respectively. As will be seen in Fig. 9, the machine consists of a 2-row Curtis disc and 10 simple Rateau wheels, this being the usual number of stages for large machines of this type when running at 1,500 revs. per minute. The steam is expanded from initial pressure down to about 50lbs. per square inch absolute in the nozzles before the Curtis disc, and after having partly given up its kinetic energy in this portion, a gradual expansion takes place in the succeeding Rateau nozzles until the final pressure is reached.

This type of machine is also built by a number of continental firms, all of which are very similar in design and construction to that shown, and adhere very closely to standard Rateau practice for the low-pressure portion. The method of blade fixing also follows the standard Curtis and Rateau arrangement, which consists of a dove-tail root for the Curtis blades, and a straddle form of blade root for the low-pressure blades. As this is a pure impulse type of machine, there is very little out-of-balance force due to steam pressure, and any slight thrust due to either reaction or other causes is taken on the main thrust block. The governing is in all cases effected by means of an oil relay, and usually all loads up to full load are controlled by throttling—the overloads being obtained either by hand or automatic nozzle valves. The coupling is in this case flexible, and is of the claw type, but in most continental designs a three-bearing arrangement is now employed, with a solid coupling placed on the turbine side of the middle bearing. With regard to the performances of this type of machine, Table I. gives a list of five recent tests, Nos. 24 to 28.

TABLE I.—*Turbine Efficiencies.*

Type of Turbine.	Date of Test.	Manufacturer.	Output K. W.	Rev. per Min	Bl Press.	Total Temp F°	Vac. at 30in Bar.	Lbs per K W Hour.	Overall Eff.	Reference
1 Parsons	1910	C. A. Parsons	5164	1200	214·	509°	29·03″	13·18	64·3	Stodola, 4th ed., p. 439
2 ,,	1908	Allis-Chalmers ...	4300	1800	186·	481°	28·04″	14·02	68·4	Sibley Jour., Eng., Jan., 1911
3 ,,		Willans & Robinson ...	5000	1000	194·	478°	28·8″	13·4	67·5	Electrical Times, 1910
4 ,,	1911	Allis-Chalmers ...	3850	1800	164·	491°	27·99″	15·40	63·5	Power, 1910
5 ,,	1903	Brown Boveri	3500	1360	156·	499°	28·92″	13·71	65·60	Zeit. D.V.D. Ing., 1910
6 ,,	—	,, ,, ...	3000	1360	165·	625°	27·1″	14·75	64·30	Die Turbine, 1911
7 ,,	1910	Richardson Westgarth	6257	1200	203·	559°	29·1″	11·9	68·4	Electrician, 1911
8 Curtis	1906	A. E. G.	3000	1500	191.	590°	29·13″	12·79	62·0	Zeit. D.V.D. Ing., 1910
9 ,,	—	G. E. C.	10816	750	190·	525°	29·47″	12·9	61·9	Trans. A.S.M.E.
10 ,,	1910	G. E. C.	8775	750	194·	451°	28·03″	15·59	61·0	Trans. A.S.M.E.
11 ,,	1911	B. T.-H.	2987	1500	154·	505°	26·92″	15·96	64.70	Engineer, 1911
12 Zoelly	1909	Howden	6383	1000	202·	520°	27·41″	14·3	67·5	Engineer, 1909
13 ,,	1910	Escher-Wyss	4189	1000	179·	557°	28·78″	13·3	64·40	Zeit. D.F.G. Turb., 1911
14 ,,	1908	F. Ringhoffer	3000	1000	170·	470°	28·4″	15·52	64·8	Zeit. D.V.D. Ing., 1910
15 ,,	—	Escher-Wyss	5118	1000	133·	549°	27·63″	15·18	65·7	Dinglers P.J., 1911
16 ,,	—	,, ,, ...	5000	1000	166·	539°	26·42″	16·13	63·9	Zeit. D.V.D. Ing., 1910
17 ,,	—	,, ,, ...	3540	1500	155·	469	28·29	15·07	64·8	Dinglers P.J., 1911
18 Rateau	1911	Oerliken	3166	1500	213·	663	29·33	11·44	66·1	Engineering, 1910
19 ,,	1910	Bt. Westinghouse ...	5170	750	197·	520	28·51″	11·3	62·50	K. Baumann, "Steam Turbines"
20 Curtis-Parsons	1910	Erste Brunner ...	7442	960	192·	584	28·26	12·62	70·3	Periodische Mitteilungen
21 ,, ,,	-	,, ,, ...	6000	960	181·	573	28·26	12·56	71·3	Zeit. D.V.D. Ing., 1910
22 ,, ,,	1910	Westinghouse, U.S.A.	9173	1800	181·	433	27·89	14·57	68·9	Trans. A.S.M.E.
23 ,, ,,	—	Brown Boveri	3053	1360	150·	505	29·08″	13·01	68·0	Dingler P.J., 1911
24 Curtis-Rateau	1911	A. E. G.	6518	1220	198·	601°	29·36	11·13	68·7	A. Christie on "Steam Turbines"
25 ,, ,,	1911	Bt. Westinghouse ...	5066	1500	190·	552	28·76	13·0	67·9	Electrical Review, 1911
26 ,, ,,	1908	A.-E. G.	4239	1500	188·3	662	29·19	11·97	64·9	Stodola, 4th ed.
27 ,, ,,	1911	Bt. Westinghouse ...	2930	1500	210·	568°	28·26	13·72	63·90	Electrical Review, 1911
28 ,, ,,	1907	A. E. G.	3169	1500	184·	592	29·19	12·74	63·0	Trans. A.S.M.E.

Pure Curtis Type.—A 5,000 kw. machine constructed on the pure Curtis principle has quite recently been installed at City Road Power Station by the British Thomson Houston Company, Ltd. The turbo set is of the four-bearing arrangement, and fitted with a claw coupling between the turbine and generator. The bearings are lubricated under pressure from a geared pump, which also supplies the pressure for operating

the governor oil relay. The turbine shaft is of forged steel, and is fitted with six Curtis wheels arranged to work from 155lbs. per square inch pressure at 180 Fah. superheat to 28in. vacuum, under which conditions a consumption of 13·6lbs. per kilowatt was obtained with a load of 5,600 kw. (this representing an over-all efficiency of 69 per cent.).

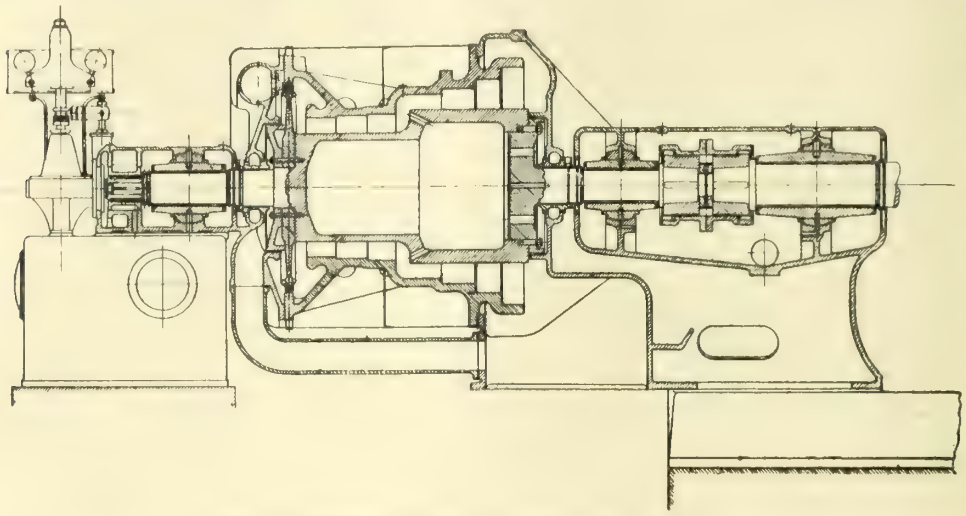


FIG. 8.—SECTION OF 8,000 KW. DISC AND DRUM TURBINE.

In these latest type machines the steam is admitted at the centre of the casing, and after passing to the governor end through some of the stages, the steam is returned to the centre of the machine, and passes through the remaining stages to the exhaust. This arrangement, no doubt, gives many advantages over the original Curtis design, as not only are the high pressures and temperatures kept in the centre portion of the machine, but a high-pressure gland (to atmosphere) is avoided; also it permits the employment of a slight re-action on the impulse blading without any out-of-balance taking place.

Conclusion.—Although the progress, both in size and total output, of turbo-driven electric generators has been enormous during the last few years, there is every reason to believe that this will be greatly exceeded in the near future. This demand for further increase in size and output will be due to a very large extent to the electrification of the various railway systems. At present the introduction of electrically-driven cars is confined to local services only, but there is no doubt that in a few years part or perhaps all the main line passenger traffic will be electrically operated.

Apart from the high economy and reliability of large steam turbo units, there are other reasons in favour of the turbo-driven electric generators for this class of work; one being the capability of holding momentary overloads even up to 100 per cent. without detriment to the plant itself, and that these overloads can be obtained automatically with practically no loss in efficiency and increased first cost. The enormous advantage of large overload capacity is obvious for this work, as it is quite conceivable that there may occur many occasions when a large starting torque is required, and should it not be possible to obtain this automatically it would necessitate keeping some of the plant on lighter loads during a greater portion of the total running time.

Finally, there is little doubt as to the high economy, reliability, and low maintenance of large turbo units. With regard to economy one has only to study some of the recent published figures (which are given in Table I.) to see efficiencies as high as 68 to 70 per cent. are possible even in sets of 5,000 kw. to 6,000 kw. output. As to the question of reliability, there is no doubt that the steam turbine can more than hold its own with other prime movers, and further, it has the great advantage that even should a mishap occur, it is never a serious one, and temporary repairs can be executed in a very short space of time, the turbine put back on load and continue its duty without much loss in economy while awaiting replacements from the manufacturers.

With regard to maintenance, or general cost of upkeep, this must necessarily be small, for providing no mishap occurs, the only wear that can possibly take place is at the bearings, governor drive, &c., and as all these parts are subject to forced lubrication, the wear is negligible. As an example of this the author had the pleasure of examining quite recently a small machine which had been running for nearly four years, during which time there was only one minor replacement, the machine having produced over 50,000,000 units of useful work, and the efficiency is not 2 per cent. less than on the day it was first tested. Although this is perhaps by no means a record, it shows in a small way what a steam turbo set is capable of doing, and that if suitable care is exercised in the design and construction, the economy, reliability, and cost of maintenance may be such as to render it far superior to any other form of prime mover for driving electric generators of large output.

The Kearney Mono-railway.—A demonstration was recently given at Olympia with a working model of the Kearney mono-railway. The car, which is one-sixteenth full size and is driven electrically, having been stopped when ascending a gradient of 1 in 7, was started again and continued its climb. It is claimed that this has never before been accomplished on such a steep gradient on a railway. It is proposed to use slopes of this kind on Kearney underground railways, each station being on the street level and the track descending to a depth of about 100ft. between stations. In this way acceleration on leaving a station will be got by gravity, and the slowing up will be brought about by ascending the hill to the next station. An indication of the great security against derailment of the car was evidenced in the following test. Kinks had been made in the mono-rail which in the full-size

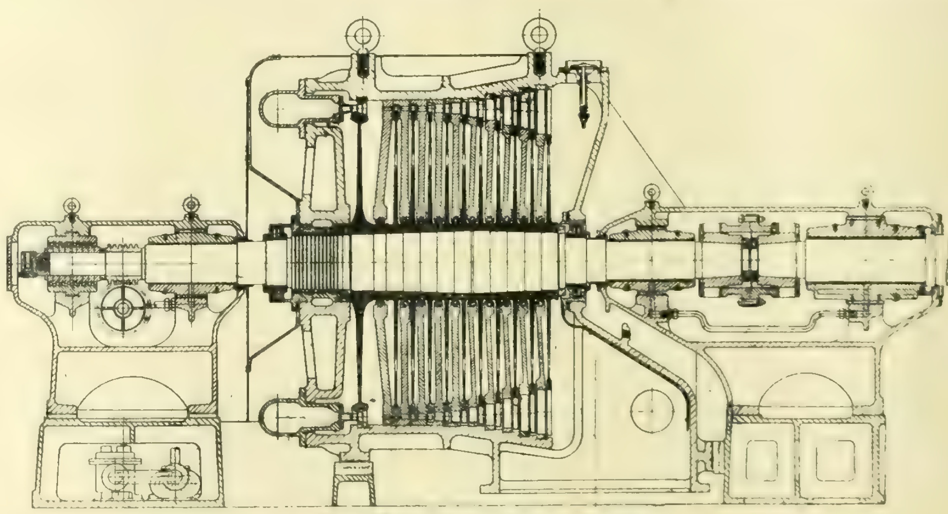


FIG. 9.—5,000 KW. CURTIS-RATEAU TURBINE.

railway would be equal to a lateral displacement of about a foot, and the car ran over them at a speed approaching 30 miles an hour without trouble. It may be recalled that on the Kearney system the car is maintained in equilibrium by an overhead rail, against the underside of which grooved wheels on the roof of the car are kept constantly pressed by means of springs. A full-sized car has now been built, and will be run on a railway half a mile long at the Ghent Exhibition next summer.

EFFICIENT PRODUCTION OF CYLINDRICAL WORK.*

BY C. H. NORTON.

TURNING is one of the oldest of the mechanical arts, and the lathe is one of the oldest metal working machines; but the lathe has been a very inefficient tool until the present time. We now have lathes so designed that they can be made efficient. I believe, however, that we are not as a rule using the modern high-power lathes as we should, and are losing what they were designed to save, viz., time; that while we use them as roughing machines we also use them as refining machines.

Most cylindrical work must finally have size within small limits and be truly cylindrical within still smaller limits, which led mechanics in the past to study the art of refined turning. When this art had reached a high degree of refinement, men discovered that it did not satisfy them and cylindrical grinding was introduced to give more refinement than could be obtained with the lathe. The natural conclusion at that time was that the grinding machine should take up the work of refinement after the limit of refinement had been reached with the lathe and the early grinding machines were, therefore, designed with this thought in view.

Later, however, it was shown that ground cylindrical work could be produced at a cost no greater than the turning alone had cost, simply by using the lathe to remove a large proportion of the metal necessary to be removed and not at all as a means of refinement; transferring the entire responsibility for refinement to the grinding machine. While some understand this and are producing cylindrical work efficiently, I believe the great majority are still under the spell of tradition, and are turning what they call "good work," work that shows care and skill on the part of the operator and accuracy in the lathe. Such care and skill with turned work is even more senseless to-day than the old-time practice of shaping acorns on all screw heads and putting cast-iron eagles on the tops of machine tools, because in case of the former the grinding machine removes all trace of the lathe's accuracy and the operator's skill in a moment of time, while the latter remained for years to gratify the taste of those who had an eye for such artistic embellishment.

The developments of the last few years have brought about the facts that, except in rare cases, efficiency in the production of cylindrical work means: (*a*) the use of the lathe as a roughing tool only, and (*b*) the modern grinding machine for refinement. Most lathe operators and most foremen seem to understand roughing to be simply the turning of work a few thousandths over the finish size, when in reality they are not roughing at all, but simply turning to a certain degree of refinement with the notion that by so doing they are (*a*) doing a creditable job, and (*b*) that they are helping the grinding machine. It is difficult to secure roughed work from lathe operators, *i.e.*, work that is not in any sense refined.

Tradition impels nearly all to consume much more time than would be necessary if the work were merely roughed, roughing being confused with a certain degree of refinement. Roughing is not refinement of any degree, and refinement does not necessarily mean perfection. There are many degrees of refinement, but never degrees of accuracy or perfection. Accuracy and perfection are final and fixed, they have no limits. Those who would produce cylindrical work efficiently must recognise the fact that different cases require different degrees of refinement, and whether the work requires a very low degree of refinement or a degree closely approaching accuracy, the lathe work, to be efficient, should be the same, viz., as rough and as cheap as it is possible to make it.

The lathe to-day should be a roughing tool only, and the grinding machine a refining tool only, not a perfecting tool. Some grinding machines may produce greater refinement than others, but none can produce literally exact and perfect cylinders. While it is true many mechanics look upon a high degree of refinement as accuracy and speak of it as such, it is easy to prove that it is not accuracy, but simply a high degree of refinement. When all recognise these facts there will be greater efficiency in the production of cylindrical work. Because these facts about roughing and refining are not well understood and men do not combine the lathe and grinding machine in a well defined and efficient manner, the machine industry and railroads are losing large sums each year and I will try to show where some of the loss occurs.

We are losing because we turn closer than about $\frac{1}{32}$in. above the finish size. I use the word about because we lose by turning carefully. To require lathe work turned to thousandths to-day is like burning money for the fun of it. We are losing by allowing workmen to use any but the coarsest feeds possible in each case, even to the use of the screw cutting gears to obtain them. Feeds as coarse as four to the inch should be used in some cases and six, eight, and ten should be quite common. When work is too frail to allow such feeds with one cut, then another, or even three cuts should be made at faster cutting speed; for, while it is true that very coarse and imperfect turning will require longer to grind than close, careful turning, the combination of coarse, cheap turning with grinding will produce cylindrical work more efficiently. The modern grinding machine will remove metal most efficiently when that metal is in the form of coarse screw threads.

High ridges do not increase the cost of production. We lose money when workmen are allowed to caliper cylindrical work on the tops of the ridges, as nearly all do. This accounts for the misunderstanding about coarse turning and the allowance for grinding. Calipering on the tops of the ridges makes it necessary to turn with relatively fine feed to enable clean grinding. To avoid this some workmen use a broad nose tool with the coarse feed, which necessitates slower cutting speed because more metal is removed than with a pointed or grooved cutting tool. Ridges left by a more pointed tool do not increase the cost of producing that work, but decrease it.

It is so simple to feed by hand a slight distance at the end of the work, where the calipering can be done correctly, however coarse may be the power feed later, and however high the ridges. Money is lost by allowing workmen to measure roughed work elsewhere than at the end; hours are wasted by operators calipering at several points, and then because of spring or tool wear, resetting and turning that portion again to secure straight work. They forget that the modern grinding machine was designed to do all of the straightening and all of the sizing, regardless of what the errors of roughing may be. They forget, or have never known, that the art of producing cylindrical work has progressed beyond that stage where it was necessary for the lathe to do its best before the grinding machine assumed the work of refinement.

The modern grinding machine is literally a correcting machine. The roughing can literally be rough, and roughness does not mean an approximate refinement. It is easy to figure the saving in time of turning a piece of work 6in. diam. by 6ft. long when the last cut before grinding is made with a feed of six per inch, instead of 32 per inch, which is very common. When it is considered that the grinding machine will grind this six per inch work to the finish size complete in less time than is required to file 32 per inch work, we see the great possibilities for saving cost with the lathe, if combined with a modern grinding machine. In some cases money is lost by roughing at all in the lathe. Please note that I say in some cases. Efficient production of cylindrical work is usually accomplished by roughing first in the lathe; but there are cases when the difference in favour of grinding without first roughing in the lathe is very great.

The most important study for those who would secure efficient production of cylindrical work is the roughing of that work. It is here that the greatest possibilities for saving lie. If all would make a careful study of the roughing preparatory to grinding instead of trying to improve upon the methods of grinding advocated by grinding machine makers, there would result a more efficient production of cylindrical work and a clearer view of the real reasons why the grinding machine maker advocates certain methods, and why the modern heavy grinding machine was introduced.

At a works where large numbers of cylindrical pieces are manufactured 1⅜in. diam. and about 10in. to 11in. long, 5 minutes was required to turn each, removing about $\frac{1}{16}$in. from the diameter, using a high speed steel tool and revolving as rapidly as the tool would stand. The point was to turn close to the finish diameter and care was taken to secure

* Abstract of paper presented before the American Society of Mechanical Engineers.

straight, smooth, and round work to save time when grinding, because they considered the grinding expensive, and that this expense must of course be added to the cost of turning. The grinding in this case was 1 minute. The total time for producing these pieces was 6 minutes. A change was made in the shape of the tool point and the size limit for turning increased. The traverse feed was increased, the cutting speed remained unchanged, and the work was turned in 1 minute each, while the grinding time was doubled, viz., 2 minutes; the saving was 3 minutes, or one-half of the original time.

Some idea of what is lost by allowing lathe work to be turned straight, smooth, and close to size before grinding may be obtained from the following illustration of actual work on some forgings about 4ft. 6in. long, turned portion to finish 2in. plus or minus 0·0005in. diam., and 3ft. long. The lathe operator turned these in the same manner that the majority of operators are now turning such work, viz., as such work was turned before grinding machines were introduced, except that 0·010in. was left on the diameter for grinding. The turning required two cuts, as there was more than ⅛in. to remove and the work was somewhat frail as well as irregular. The first cut was considered by the workman a very coarse heavy cut; the second was like the last cut in the majority of shops, viz., it gave what the lathe men and most foremen call "a good job." When ready for grinding the time consumed by turning was a total of 25½ minutes. This appears to be too slow, but the forging was too slim to allow little, if any more, with one rough cut, and the lathe was an old-time weak power frail machine. The grinding time on this was 3 minutes, making a total of 28½ minutes.

When tradition was ignored and the work was made ready for grinding in the proper way, the following saving was accomplished: Two roughing cuts were taken, because (*a*) the lathe was not powerful, and (*b*) the work was frail. The feed was 10 per inch, cutting deep grooves; the time complete ready for grinding was 9 minutes. The work was not straight, and was what lathe men would style "a very poor job." The grinding time to the exact limits was 9 minutes, or three times longer than with the more careful turning; a total of 18 minutes, a saving of 10½ minutes on each forging. An attempt to rough this work with one cut instead of two resulted in a loss of 2 minutes. A modern lathe having more power with the direct belt would have carried the same feed and depth of cut at higher cutting speed with a still further reduction of time. This shows what may be accomplished with weak low-power lathes.

To install high-power lathes and continue to turn just as smoothly and accurately as of old, simply allowing a few thousandths for grinding, would seem the height of wastefulness. Whether high-power lathes or old low-power lathes are used mechanical industries are losing an enormous sum each year because of the lack of understanding of the real problem affecting the efficient production of cylindrical work, which is the proper combination in each individual case of rough turning and grinding.

Some idea of what we are losing by not wearing our "thinking caps," is shown by the following: Some plain shafts 15/16in. diam., 62in. long were to be made to ordinary limits of size and finish. Tests were made to determine whether it was better first to turn these or to grind direct from the rough bars. The turning required 6 minutes ready for finish grinding, while to grind off the same amount as was turned off required 9 minutes. A number of mechanics pronounced it cheaper to turn the shafts first. "Of course." But in this case after turning in 6 minutes, each shaft required straightening before grinding, which consumed 10 minutes, totaling 16 minutes. When the roughing was done by grinding instead of turning no straightening was necessary, and the roughing cut was removed in 9 minutes. In this case, therefore, the turning was actually lost. There may be similar cases where the shafts will require some little straightening even if roughed by grinding, so that each case should be investigated instead of making a rule that all must or must not be turned first. Usually, however, no straightening is necessary when the roughing is done by grinding.

Money is being lost because the majority of designers have not kept pace with the development along these lines. A well-known runabout motor-car has a crank shaft, which if made about 1in. longer over-all could be produced for 50 cents less on each crank. When it is considered that about 30,000 of these cranks have been made, representing a possible saving of £3,000, we see the importance of considering the combination of lathe and grinding work.

Another feature affecting the cost of production is the matter of ordinary shoulders. This is overlooked by many designers and practically all draughtsmen. It is easy to draw two sharp lines that cross each other and form a sharp corner, and the fact that it costs less to provide room for the shoulder fillet on the other member than to make a sharp corner in the cylindrical member is lost sight of. This no doubt is the result of the experience of the past when there were no powerful grinding machines to locate and form such shoulders cheaper than the lathe. Shoulders to be made with the grinding wheel require a slight fillet.

When numbers of duplicate pieces are to be produced and a small fillet is allowed, not only can the cylindrical portion be roughed with the lathe and not at all refined, but the shoulders can also be roughed, because the grinding machine, when required, is provided with a locating bar. By the use of this bar, the exact location of all shoulders can be secured by grinding and without measuring. At the same time the cylindrical portion can be ground with the same grinding wheel. The roughing in the lathe can be done with the same tool that roughs the cylindrical portion, because the lathe in this case is not required to give to the shoulder any particular shape. When it is found best to locate and finish shoulders with the lathe because there is no locating bar for the grinding machine, it should not be necessary to neck in at the shoulders for grinding. This is an old and out-of-date notion, for, with a shoulder cut sharp by the lathe tool, the grinding does not materially change the corner.

A more efficient method when no locating bar is at hand is to rough the work in the lathe, leaving the shoulders about $\frac{1}{32}$in. long and whatever angle the roughing turning tool may form. Next grind the cylindrical portion and at the same time cut out the angle at the shoulder with the grinding wheel. The work should then go to a lathe where a more skilful operator can locate the shoulders exactly; if a sharp corner is really necessary it can then be made.

A lot of 60 countershafts, 35 point carbon steel, finish size $2\frac{3}{16}$in. plus or minus 0·0005in. by 66in. long, turned 8 pitch, leaving about $\frac{1}{32}$in. for grinding; ground complete at the rate of 35 minutes each; cubic inches ground off, 278; cubic inches of steel removed for every cubic inch of wheel wear, 20·7; total cost of wheel for 60 shafts, 19d.; total cost of power, 17½d.; wheel used, 24 combination grade L alundum; radial depth of cut, when roughing, 0·001in.; radial depth of cut, when finishing, 0·0005in.; surface speed of work, roughing, 42ft. per minute; surface speed of work, finishing, 35ft. per minute; table traverse, roughing, 11ft. per minute; table traverse, finishing, 10ft. per minute; steady-rests "multiple system."

To produce cylindrical work efficiently we must make a study of all that affects the problem in each individual case instead of following tradition which is costing so much each year. Lathe builders are offering some very efficient roughing lathes, but are we roughing with them? I think not in most cases. The real roughing lathe needs a good system of multiple steady-rests to enable rapid and deep coarse cuts. Will someone come forward with such a system of steady rests?

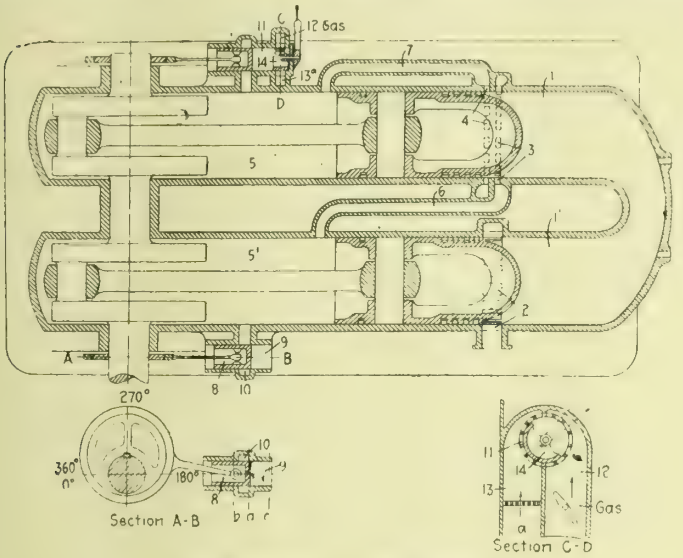
Instead of our lathe departments and grinding departments being separate as is common now, there should be one department of cylindrical work under one head. This would check the tendency of the lathe department to treat their work as a finished product, and the tendency of the grinding department to insist upon close careful turning in order to make a better showing of the grinding time, regardless of the real cost of production.

There is much yet to be learned about the preparation for grinding of cylindrical work; no two pieces of work require the same lathe treatment. There is a great need for thinking men as foremen and operators. Such men can effect great savings by working out in each case the best combination of turning and grinding of cylindrical work.

Railway Electrification in America.—Powers have been granted to the Great Fall (Montana) Power Company for the electrification of 450 miles of track on the main line of the Chicago, Milwaukee, and Puget Sound Railway between two points in Montana and Idaho.

A NEW TWO-STROKE CYCLE ENGINE.

THE January Proceedings of the American Society of Mechanical Engineers contains a description of a new 2-stroke cycle internal-combustion engine designed by Mr. Urbani. It is shown in the accompanying illustrations and consists essentially of two cylinders 1 and 1′ connected together in U form. One of the cylinders is provided with the exhaust ports 2 and the other with the openings for scavenging air 3 and gas 4. The air and gas pumps, which may also be independent of one another, are shown at 5 and 5′. In the two cylinders move two pistons having equal cranks making the same angles with the crank shaft. The action of the engine is simple. Suppose that the pistons are at the right-hand side dead points, and that to the right of them is a suitably compressed explosive mixture. When this is ignited an expansion follows, and the pistons move to the left. The exhaust ports 2 open first, and the pressure in the cylinder rapidly falls to about 4·2lbs. to 5·6lbs. per square inch above atmospheric.



URBANI TWO-STROKE CYCLE ENGINE.

At this point of the path of the piston the port 3 opens, admitting scavenging air previously compressed in 5′ to a pressure slightly above 4·2lbs. to 5·6lbs. per square inch (so as not to produce eddies in the cylinders). Still later, when the pressure in the cylinder has had time to fall below 4·2lbs. to 5·6lbs., the gas comes through duct 7 and port 4 from pump 5 compressed to somewhat more than the pressure prevailing at that moment in the cylinder, so as to produce eddies and thus help the gas to make a thorough mixture with the scavenging air. On the back stroke of the piston the ports close in the reverse order, first the gas, then the air, and finally the exhaust. The process is somewhat similar to that of the Oechelhäuser motor, but the engine may be made double acting, tandem, &c. The air regulator consists of a little piston 8 moving in the cylinder 9 having no head but provided in the middle with a circular passage 10 communicating with 5′. This little piston has an eccentric lagging 90° with respect to the main crank. While the crank makes the angle 0° to 180° corresponding to the period of intake of air, the piston oscillating between the positions *a* and *b* lets open the annular passage 10 by which air penetrates to 5′. During the compression of the air, while the main crank passes through the angle 180° to 360°, the eccentric describes an angle 90° to 270°, and the little piston oscillates between *a* and *c* regulating the communication between 5′ and the atmosphere. This arrangement is interesting in that the opening and closing of the annular passage 10 occur always when the piston 8 is at its maximum velocity. A somewhat similar arrangement is provided with respect to gas.

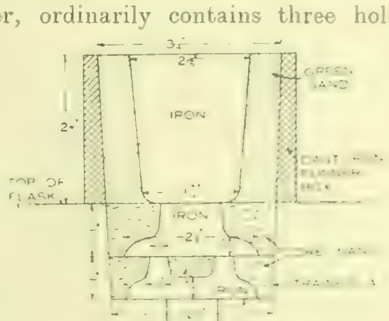
North-east Coast Institution of Engineers and Shipbuilders. A meeting of this Institution will be held on the 22nd inst., at 7-30, in the Lecture Theatre of the Literary and Philosophical Society, Newcastle-on-Tyne, when the discussion on the "Arch Principle of Ship Construction," by Maxwell Ballard, will be resumed. On the 24th inst., at 7-30, a meeting will be held in the Lecture Theatre of the Literary and Philosophical Society, Newcastle-on-Tyne, when a lecture on "The Practical Use of the Iron Carbon Equilibrium Diagram, with Special Reference to the Critical Points A.1.2.3., and the Burning of Steel," will be delivered by J. E. Stead, D.Met., D.Sc., F.R.S.

EFFECT OF POURING TEMPERATURE ON STRENGTH OF ALUMINIUM.

AN elaborate series of experiments have been made by Mr. H. W. Gillett on the effect of the pouring temperature on the strength of aluminium castings, the results of which were published in the transactions of the eighth International Congress of Applied Chemistry. The experiments showed that the tensile strength of aluminium alloys was greatly influenced by the size of the constituent crystals. The finer the grain, the stronger was the metal. In some 53 experiments made the bars used for testing averaged nearly 20 per cent. stronger when poured cold than when poured hot. Exceptions were the alloys of aluminium containing 2 per cent. of manganese, and also the ones containing 5 per cent. of magnesium. The manganese alloy had such a low elastic limit that it was seldom of commercial use. The alloys with magnesium oxidised so readily when melted that it was difficult to make castings that did not contain dross, and hence were weak. It was stated by Mr. Gillett that the aluminium alloy consisting of 92 per cent. of aluminium and 8 per cent. of copper was the one most extensively used at the present time for making sand castings, and easily 90 per cent. of all the aluminium castings made were produced by the use of this mixture. The addition of small amounts of manganese, titanium, iron, or antimony to the aluminium and copper previously mentioned increased the strength of the casting when poured hot, while nickel, chromium, cadmium, or bismuth seemed to be without much influence. Any of these elements, however, caused brittleness and increased the resistance to impact. The heat of the bars poured hot averaged from 1,550° Fah. to 1,600° Fah. These temperatures, however, were such as to decrease the tensile strength of the cast bars nearly 20 per cent. The best pouring temperature for the 92 per cent. aluminium and 8 per cent. copper mixture, as well as the other commercial alloys, was found to be about 1,225° Fah.

AN EFFECTIVE SKIM GATE.

THE accompanying illustration, for which we are indebted to "The Foundry," shows a skim gate, designed by T. H. Gilvear, foundry superintendent of the Berlin Machine Works, Ltd., Hamilton, Ontario. The gate is made in two sections from a core sand mixture, and a third section, consisting of a cast-iron runner box moulded to form a pouring basin, is superimposed on the lower sections. The lower section of the gate, which is a strainer, ordinarily contains three holes through which the metal is strained into the mould, and a gate of this size is sufficiently large for castings averaging 50lbs. in weight. However, this gate can be used for making castings weighing 400lbs. by increasing its size and adding to the number of openings through which the iron flows into the sprue of the mould. It will be noted from the illustration that the iron flows from the runner box into a gate having two openings into the strainer. It is claimed that any dirt contained in the iron, particularly in the first few drops poured, cannot penetrate the mould, as it is forced aside in the strainer by the following metal. In the foundry operated by the Berlin Machine Works, Ltd., several hundred of these gates are used daily and the number of bad castings resulting from dirty metal has been materially reduced.



Fatal Steam Pipe Explosion on a Liner. An explosion took place on Saturday last on the Royal Mail Steam Packet liner "Araguaya" in Southampton Docks. Three men were killed and several injured. The accident occurred in the engine-room, and was caused by the bursting of an auxiliary steam pipe, the stop cock of which was blown off.

THE CUTTING AND GENERATION OF GEAR TEETH BY MODERN GEAR-CUTTING MACHINERY.*

BY VINCENT GARTSIDE.

GEARING and gear cutting is one of the most important branches of the engineering trade at the present time, and has developed considerably to meet the requirements of the motor and the machine tool industry. Cut gearing is gradually developing on the heavier lines for millwrighting work, gearing for colliery machinery, and rolling mill gearing. In fact, accurate cut gearing is being called for in practically every branch of the trade. We see the greatest results, however, in the motor and machine tool trades. Some of the finest and most accurate gearing is seen in the gear boxes for motor-cars, and the bevel gears for the differential back axle drives and the steering and driving worms and wheels. Then in the latest machine tools we have the all-gear headstocks for lathes, &c., and gear boxes for feed and speed changes. The large amount of forged steel gearing which is now called for would be impossible to produce but for the modern methods and machines for cutting gears. Although it is the author's intention to deal with this subject from a practical standpoint, it is necessary in the first place to consider the different tooth forms in most general use, and their geometrical construction, because these principles are involved in the manufacture of the tools and machinery for cutting and generating the teeth.

FORMS OF TEETH.

The most common forms of teeth are those with involute

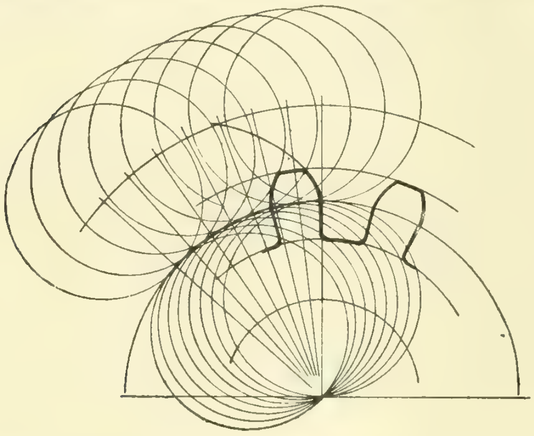


FIG. 1.

and cycloidal curves, or modifications of these forms to facilitate the manufacture.

The Cycloidal Tooth.—The cycloidal system is the one which was in most general use years ago, but owing to the practical difficulties, first in the accurate production, and then in its use, it has practically lost ground until at the present day it is very seldom heard of, particularly with regard to the smaller cut gears. It is still used by some of the older firms of millwrights, but mostly in the form of cast teeth made from old patterns. Even where the teeth are cut they are generally cut with disc cutters, or copied from formers, and are seldom generated. To-day the cycloidal system is known as the double-curve system, because the teeth are formed of one curve above the pitch line and another curve below the pitch line. In laying out these curves the face of the teeth are described by a point on a circle rolling on the inside of the pitch circle, and the flanks by a point on a circle rolling on the outside of the pitch circle, the diameter of the rolling circle for the usual standard of teeth being equal to half the pitch diameter of a 12-tooth pinion, the reason for this being that the 12-tooth pinion flanks made with size of rolling circle are radial lines. See Fig. 1. In the rack, owing to the circle rolling above and below a straight line, both the face and flank are the same curve, only the reverse of each other. See Fig. 2.

The reason that this system held favour in the early days was because so little was understood about the other forms of teeth. Also, it is a good strong shape of tooth, and runs well when well made. The greatest objection to it, however, is the difficulty of manufacturing the tooth curves, and that gears made to this system allows no variation whatever in the centre distance. This particular form of tooth was generally set out by means of the odontograph introduced by Prof. Willis, known as the Willis odontograph, but this has been superseded by the more modern method introduced by George B. Grant, and what is known as the Grant three-point odontograph, particulars of which are given in the Appendix. In the author's opinion it is a good form of tooth for slow running heavy gearing, in fact, a few years ago one of the leading heavy tool makers adopted this system for their heavy gearing, with the rolling circle equal to half the diameter of

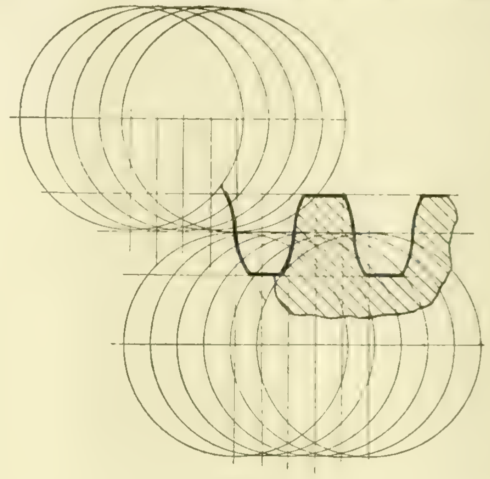


FIG. 2

an eight-tooth pinion, in order to get a stronger tooth in the pinions, making the flanks curves instead of radial. The difference is shown in Fig. 3.

The Involute Tooth Form.—This form of tooth is most generally used, because of its many practical advantages. The chief advantage is that the true involute rack has straight sides which can be easily produced, and the wheel teeth are comparatively simple curves. These two features will be appreciated when the different methods of producing the teeth are described. The next is that involute gears will run correctly even if they are not placed at correct centre distance, the only effect being more or less backlash. Another, and a great advantage too, is the flexibility. Now that we have so many generating machines, it is possible by this means to cut involute gears to gear at special centre distances, and by simple modifications to get stronger shapes of teeth where other conditions allow, by simply modifying the diameters of the blanks, these shapes being obtained by the standard tools. Fig. 4 shows a simple involute curve. It is constructed by

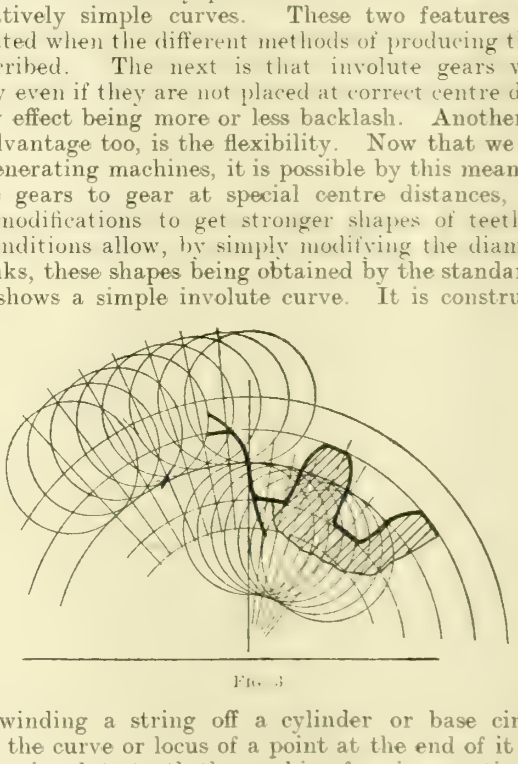


FIG. 3

simply winding a string off a cylinder or base circle and striking the curve or locus of a point at the end of it at A.

In the involute tooth the working face is a portion of this curve, and one peculiarity of the curve is that as the diameter and number of teeth of the wheel increases the involute becomes flatter and flatter; when you increase the diameter infinitely until you have a rack, the profile of the tooth becomes a straight line. On the other hand, when you reduce the diameter and number of teeth to the smallest pinion, the teeth become curved so much that the strength of the pinion has to be considered.

When designing involute gears the first thing to determine is the pressure angle, or the angle of the line of action. In

* Paper read before the Manchester Association of Engineers, January 11th, 1913.

the cycloidal system this angle is approximately 15° with the pitch line of the rack. It was found by the early designers that by adopting this angle for the involute gear a fair approximation to the curve could be obtained by laying out the pitch diameter of a gear, and with a radius quarter the pitch radius, striking a curve, as shown in Fig. 5, from a centre on a circle half the diameter of the pitch circle; Fig. 5 shows the curve set out for a 30-tooth gear, and for this number and over gives a fair approximation, and by constructing the line of action normal to the curve it will be found that the rack tooth face, which is at right angles to the line of action or pressure angle, makes an angle of 14½°

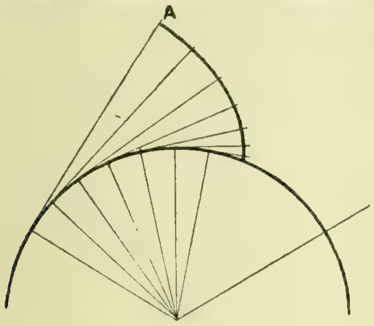


Fig. 4.

with the pitch line of the rack. It was on this method of laying out the curve that the early involute standard was constructed. Below 30 teeth, however, modifications of this system were necessary, because it was found that the pinion tooth faces were rounded off too much, and that the flanks were too much undercut when the teeth were set out with a single curve, as shown in Fig. 6.

The face of the pinions below 30 teeth, therefore, were corrected by setting out the true involute curves, and the flanks were made parallel for a short distance, and then filled in with large fillets, because undercutting was an impossibility when milling the pinion teeth with single cutters, as will be seen from Fig. 6. At the same time the parallel flanks to the pinions did not allow the straight-sided rack teeth to work without interference, so that the points of the rack teeth had to be rounded off slightly to allow for this. Fig. 7 shows the modified rack and a 12-tooth pinion, the approximate single curve being shown in dotted lines. Most of the corrections were, however, arrived at by practical methods, such as laying out templates and running them together, and getting good curves by trial. It is only within the last few years that these corrections have been treated on definite lines. George B. Grant introduced the system of making the pinions with radial flanks below the base line, and making the rack with epicycloidal points, as Fig. 8, and he made

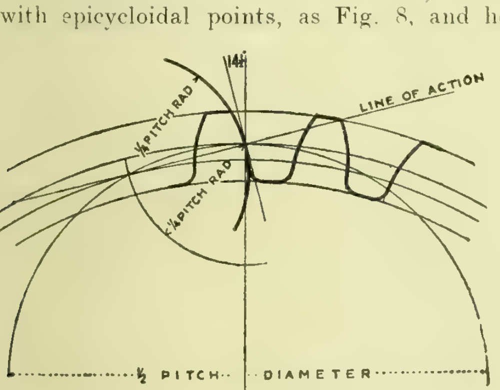


Fig. 5

large templates of the different numbers of teeth and ran them together, and tabulated his results, and arranged an odontograph. In the Appendix this is given as the Grant odontograph for the involute gear, which the author has used for laying out the tooth curves for single cutters for a number of years, and which has given excellent results. One particularly good feature of this system is that the cutters for the pinions, when made with relieved teeth, cut much better, owing to the space below the base line being wider at the top than at the root.

Since the introduction of the generating machines, however, we have got nearer the true involutes, because the majority of the machines generate from the rack, and the straight sided rack being the easiest to produce is generally used as the starting point. In the different methods of generating, however, slight modifications are made to meet practical requirements, and these will be dealt with as the various methods are described. The following diagrams, Figs. 8 and 9, show 15 per cent. and 20 per cent. involute racks and pinions.

Different Processes of Cutting the Teeth.

The different processes of cutting the teeth can be divided into two sections, non-generating and generating.

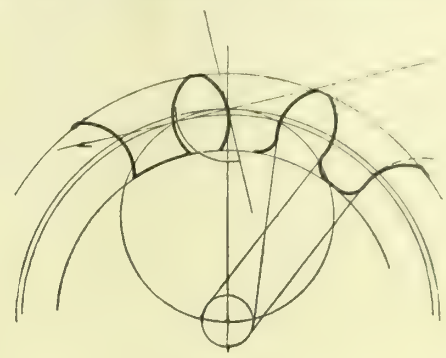


Fig. 6

(1) **Non-generating.** — We can sub-divide the first heading again into three sections: A, milling; B, planing; and C, forming.

Under A the tooth forms are dependent entirely on the tool used, and are not dependent in any way on the particular movements given to the tool or the blank during the process of cutting the teeth. The most common process under this heading is the milling by disc or rotary cutters where the profile of the cutter teeth is the same as the tooth space required to be cut. It is the oldest method of producing the teeth, and is still the most general, although great changes have taken place in the types of cutters used. Curiously enough, however, since the introduction of the generating machines this method seems to gradually tend to be used for the very smallest and the very largest gears, such as clock gears and the very largest mill gearing. This method is applicable to the cutting of spur gears, pinions, racks, spiral gears, single and double helical gears, worm wheels with the teeth at an angle, and worms and bevel gears. But the latter wheels cannot be cut theoretically correct by this method.

Under this heading we have also the process of cutting with end mills. This process was applied years ago to the cutting of large spur gears and pinions, the teeth being generally roughed out by planing, shaping, or slotting, and

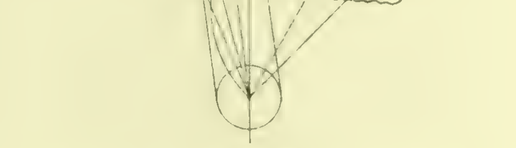


Fig. 7

then finished with large end mills of the shape of the tooth space, as Fig. 10. This method has recently been re-introduced for the cutting of single and multiple helical gears of both the spur and bevel type, and also racks. Up to a few years ago it was the principal method of producing the latter type of gear, and was generally performed by slotting machines, and for gears over three-quarter P is the chief method to-day.

Under B the profile of the planing tool is the same as the tooth space required. This method is applicable to the

cutting of spur, spiral, bevel gears, and racks. A few single helical gears have at times been produced by this method of planing or shaping.

Under C the tooth form is dependent on a guide or former, which may be an exact reproduction of the tooth shape, or it may be an enlarged reproduction, when some pantograph or proportional reducing mechanism is provided. It is necessary also in this process that the tool should be kept accurately ground to a certain shape, determined by the particular machine used. It is a process which is largely used in the

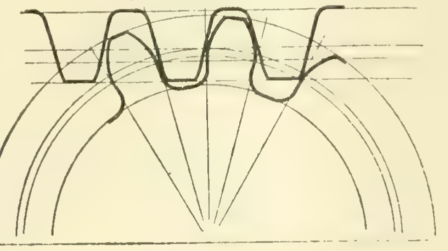


FIG. 8.

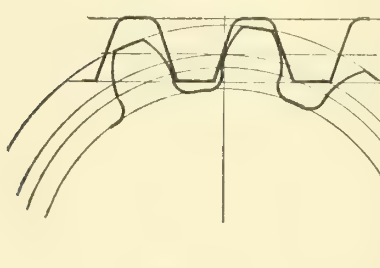


FIG. 9.

cutting of large spur and bevel gears, and is particularly good for the reproduction of teeth of special shapes in large gears, because it is often necessary to make gears to specified shapes. It is sometimes required to make gears to gear with others where the shape is not standard, and where it would not warrant the expense of a special cutter. No gear cutting establishment that caters for the larger and heavier gearing can do without the machinery for the cutting of gears by this process.

(2) **Generating.**—When the teeth are cut by the generating process the shape of the teeth is not entirely dependent on the shape of the tool, but is also dependent on the movement given to the blank in relation to the tool during the process of cutting. One class of machines generates on the principle of a rack rolling into a wheel, and the other class on the principle of a wheel rolling into another or into a rack.

The earlier generating machines were chiefly planing machines, the tool and blank moving together, so that the point of the tool generated an involute curve, first one side of the tooth and then the other by reversing the tool, and finishing the wheel by dividing the blank round for successive teeth; sometimes one side of the tool is used and sometimes

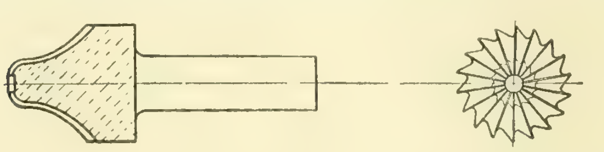


FIG. 10.

both sides, the tool representing a tooth in a rack. A modern application of the latter principle is, however, now in use, where the cutter has a number of teeth in the form of a rack. In the case of generating from a wheel, the cutter is in the form of a pinion, and it revolves round in relation to the blank, thereby generating as it rolls round.

In all the above processes the teeth are planed by giving an extra reciprocating movement to the tool, as in an ordinary shaping, slotting, or planing machine. These processes have up to the present time only been used for spur and spiral gears, and in the case of the single pointed tool process also for bevel gears.

Another process is the hobbing process. This is by no means a new process. The principle is the use of the rack as a generator, and has been in use for years for the generation of worm wheels, the hobs being often worms with gashes, the wheels being first gashed out with ordinary gear cutters, and finished by these hobs. On the introduction of the Universal relieving lathe it became possible to make hobs commercially with suitable relief, so that the wheels could be cut from the solid, and then the hobbing of spur wheels came into vogue. In fact this latter process is applicable to all kinds of wheels except bevels.

Having described the principles of the tooth formation, and enumerated the different processes of cutting the teeth, we will now pass on to the methods of applying the above to the cutting of different types of gears. Before proceeding, however, it must be noted that in order to produce first-class and accurate gearing, the blanks must be accurately bored and turned. They must run true when mounted on the machines, and in order to ensure this the work mandrels should be made of the best materials, and should frequently be tested for truth, as they might get bent by accident or careless handling. In mounting the blanks on the mandrels see that there is no dust or chips between the collars, also see that the bosses on the gears are parallel, or the work will be thrown out of truth by the tightening of the nuts for holding the wheels. It is necessary also to see that the wheel is supported in a proper manner to take the thrust of the cutting tool so that the wheel does not spring during the process of cutting. And, finally, the machines must be built in accurate alignment, and of such strength as to be absolutely rigid under the heaviest cuts. In the generating machines the shafts which transmit the various motions between the tools and work should be of ample diameter and strength, so as to reduce the effect of torsion to an absolute minimum, otherwise output has to be sacrificed in order to obtain the necessary accuracy.

(To be continued.)

SMITH'S MOULDING MACHINE.

THE accompanying illustrations show a simple arrangement for lifting the box off the pattern plate of moulding machines, the invention of Mr. W. G. Smith, 41, Tantarra Street, Walsall, Fig. 1 being a perspective view with the moulding box closed down on the pattern plate, and Fig. 2 a perspective view with the box raised from the pattern plate. In this arrangement there is provided a bifurcated lever consisting of a pair of side arms A pivoted through the lugs B to the sides of the pattern plate C. The horizontal limb of each arm A is made with a projection D to which are connected links E coupled to a bar F secured to a pedal G. Upon the other and acting end of the arms A are rollers H turning in

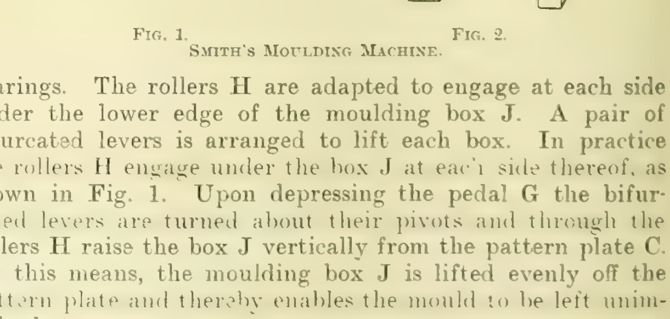


FIG. 1. FIG. 2.
SMITH'S MOULDING MACHINE.

bearings. The rollers H are adapted to engage at each side under the lower edge of the moulding box J. A pair of bifurcated levers is arranged to lift each box. In practice the rollers H engage under the box J at each side thereof, as shown in Fig. 1. Upon depressing the pedal G the bifurcated levers are turned about their pivots and through the rollers H raise the box J vertically from the pattern plate C. By this means, the moulding box J is lifted evenly off the pattern plate and thereby enables the mould to be left unimpaired.

Royal Institution Lecture.—The Royal Institution authorities have arranged for a lecture to be delivered by Prof. Arnold, on January 24th, dealing with "Recent Advances in Scientific Steel Metallurgy."

CAUSE AND PREVENTION OF ELECTRICITY ACCIDENTS IN MINES.

THE Annual Report, Part II., for 1911, of the Chief Inspector of Mines, recently issued by the Home Office, contains a summary by Mr. Robert Nelson, H.M. Electrical Inspector, of the accidents due to the use of electricity in and about mines during the year 1911, and although the information is somewhat belated, it is nevertheless interesting, as it furnishes an account of the causes of such accidents and the methods to adopt to prevent their recurrence. Electricity was, according to Mr. Nelson, newly introduced into 46 mines in 1911, as against 40 in 1910. Of this total, mines in Scotland and Wales accounted for 20 and 13 respectively. The electricity special rules in force during 1911 merely required that the introduction of electricity should be notified, no particulars were asked for, and none, as a rule, were given. This matter has, however, been remedied by the Coal Mines Act, 1911, and a complete classification of the different systems of distribution, together with a measure of the growth of the use of electricity in mines, will be made possible for the future. Such particulars as are available show that the high-pressure alternating-current system was introduced into five mines, the medium-pressure alternating-current system into 11 mines, the medium-pressure direct-current system into 13 mines, and the low-pressure direct-current system into four mines. In the latter case the current was introduced in each instance for lighting purposes only. The number of electrically-driven coal-cutting machines in use at the end of 1911 was 998, an increase of 125 over those in use at the end of 1910.

FATAL ACCIDENTS IN 1911.

During the year 1911 there were in all 14 fatal accidents reported to and investigated by H.M. Inspectors of Mines, causing in all 15 deaths. Of these, two accidents, causing three deaths, though reported to and investigated by the inspector of the district, had, however, strictly speaking, no connection with the use of electricity in and about mines. The first occurred on May 1st on the roof of an asphalte shed at the New Great Rocks Quarry, Peak Forest, Derbyshire, and it resulted in the death of one man. The second occurred on May 9th above ground, at least half a mile from the nearest mine shaft, and in this case two men were killed. The two men each received a fatal shock from a live stray wire supporting one of the poles of a 3,000-volt three-phase transmission line about half a mile from the Lower Duffryn Colliery, Mountain Ash, Glamorganshire. These accidents cannot be held to have any bearing on the use of electricity in mines, and there is no need, therefore, in that connection to discuss them further. During the year 1910 there were in all 21 fatal accidents in and about mines, causing 21 deaths, and the figures for 1911 directly comparable with these figures for 1910 are 12 accidents and 12 deaths. There were therefore, if the comparison be confined to "in and about" mines, nine fewer fatal accidents in 1911 than in 1910 and nine fewer deaths. Of the 12 fatal accidents above referred to 11 were electric shock accidents, the remaining one being due to an ignition of firedamp by electricity.

Fatal Ignition of Fire-damp by Electricity.—On April 12th a motor driver at the Ynyscedwyn Colliery, Ystradgynlais, Breconshire, was so badly burnt by an ignition of gas in his motor-room that he died the same night. The system of supply at the Ynyscedwyn pit is direct current at 500 volts. In that part of the pit in which the accident occurred safety lamps only were used, but the presence of gas appeared nevertheless to have been quite unanticipated. The motor driver explained before he died that at the time of the ignition he was in the act of breaking the motor circuit by means of a liquid controller. It is thought that some temporary derangement of the ventilation (the leaving open of a door) caused an accumulation of gas in the motor-room, which was near some old workings, and that this gas was ignited by the arc formed by the breaking of the motor circuit at the surface of the liquid in the controller. It is clear from what has been said that the type of apparatus in use was in no sense proof against open sparking, but it was represented at the enquiry that the safety lamps were in use at the mine mainly as a precaution, and that no gas had been seen near the motor for years.

Electric Shock Accidents.—Of the 11 electric shock accidents above referred to, two took place on the surface and nine below ground. Of the two surface accidents one occurred on a low pressure alternating current system, the other on a medium-pressure direct current system. Both were on lighting circuits. In the first case the victim is thought to have touched a metal lamp shade which had, in some way not subsequently discoverable, become live. Though the pressure was as low as 220 volts (alternating) the shock proved fatal. The second accident was of an unusual character, as the evidence at the enquiry showed that the practice of giving shocks had been introduced in the surface workshops of the mine (where the accident happened). The position in which the body was found, for no one witnessed the accident, and the attending circumstances, left no doubt that the deceased was either himself arranging a practical joke or that he had been the victim of one. The pressure was 500 volts direct current. Of the nine underground accidents seven occurred on medium-pressure alternating current systems and two on medium-pressure direct-current systems. That is to say, all the underground accidents were on medium-pressure systems. The circumstances of each of these nine accidents have been considered, with the result given by the following table:—

Due to:—	Accidents	Deaths
1. Faults as regards the earthing of outer coverings of apparatus, switchboard frames, &c.:—		
(*a*) Total absence of any connection to earth	2	2
(*b*) Break in continuity of earth connection	1	1
(*c*) Outer covering earthed but connection with earth inefficient	3	3
2. Contact, direct or indirect, with live parts of cables:—		
(*a*) Direct contact with a live cable exposed through abrasion of the insulation.........	—	—
(*b*) Contact with a conductor (*e.g.*, a haulage rope) made live by its contact with a live cable exposed through abrasion of the insulation...	3	3
3. Accidental contact with uninsulated live parts of apparatus	—	—
	9	9

The above table may be summarised thus:—

Due to:	Accidents	Deaths
1. Contact with outer coverings of apparatus live through the absence of, or an inefficient, earth connection	6	6
2. Defective insulation of cable system...	3	3
3. Contact with uninsulated live parts...	—	—
	9	9

It will be seen that the provision of proper connections to earth might have been the means of preventing six of the accidents, or two-thirds of the total number. For the period between January 1st, 1905, and December 31st, 1911, that is to say, in the last seven years, electric shock below ground has been responsible for 62 recorded accidents and 64 deaths. I have carefully considered the available information in regard to all of these accidents (a large proportion were per-

sonally investigated by me) and they may, I think, justly be analysed as follows:—

Due to:—	Accidents.	Deaths
1. Contact with outer coverings of apparatus live through the absence of, or an inefficient, earth connection	28	30
2. Defective insulation of cable system...	23	23
3. Contact with uninsulated live parts...	9	9
4. Other causes	2	2
	62	64

It is remarkable that the mere provision of a satisfactory connection to earth for all outer coverings might have prevented nearly one-half of the total number of electric shock accidents which have occurred in mines since the beginning of the year 1905. The most recent figures, viz., those for 1911, in so far as a general conclusion may be drawn from the experience of a single year, tend to show that that proportion is not diminishing, and the importance of paying careful attention to earth connections below ground is at once apparent.

Although it must always be remembered that the careless or improper use of electricity below ground might cause a serious accident which might very materially affect any proportionate figure, the fatal accidents due to electricity in mines represent almost exactly 1 per cent. of the fatal accidents due to all causes during the year 1911

SUMMARY AND ANALYSIS OF FATAL ACCIDENTS DUE TO THE USE OF ELECTRICITY IN MINES IN 1911.

Due to:	Accidents.	Deaths
Electric shock—		
On surface:		
At coal mines	2	2
At metal mines	—	—
Below ground:		
In coal mines	9	9
In metal mines	—	—
Ignition of firedamp by electricity—		
In a coal mine	1	1
	12	12

Fatal Accidents due to the use of Electricity in and about Mines in 1911, *with brief particulars.*

Name of Mine.	Situation	Date and Nature of Accident.	Circumstances of Accident.
Ashington Colliery	Ashington, Northumberland.	January 25th.. Electric shock.	Deceased received a fatal electric shock from the motor switch handle. It was subsequently found that a small screw in the switch which was in contact with a live part had worked loose and made contact with a part of the switch in metallic connection with the handle. The switch was enclosed in a cast-iron box with the handle outside so that at the time of the accident the whole box would be live. There was no earth connection for the box. System: Three-phase current, 500 volts, neutral point earthed. Verdict: Accidental death.
Halesfield Colliery	Madeley, Shropshire	January 31st.. Electric shock.	Deceased received a fatal electric shock by contact with a loose length of disused haulage rope left in the road, which haulage rope was itself in contact with a live part of a cable exposed through abrasion of the insulation. System: Direct current, 465 volts. Verdict: Accidental death.
Polton	Edinburgh ..	February 13th Electric shock.	The evidence at the enquiry showed that the practice of giving shocks had been introduced in the surface workshops at the colliery. Deceased was either himself arranging a practical joke or he was the victim of one. System: Direct current, 500 volts. Verdict: Death by electric shock.
Devon Colliery	Alloa, Clackmannan.	February 28th Electric shock.	Deceased received a fatal electric shock by contact with a cable purporting to be an earth cable which was in contact with a live cable at a part where the insulation had become abraded. Deceased was working some 250 yards out-bye from the point of contact between the live cable and the supposed earth cable when he touched the latter. The earth cable was inefficiently earthed. System: Three-phase, 600 volts, neutral point insulated. Verdict: Accidenta ldeath.
Ynyscedwyn Colliery	Ystradgynlais, Breconshire.	April 12th .. Fatal ignition of firedamp.	Deceased was in the act of stopping his motor by breaking the motor circuit at the surface of the liquid of a liquid controller when the resulting arc ignited some gas which had accumulated in the motor room, it is thought through some temporary derangement of the ventilation. The motor room was near some old workings,'but gas had not previously been seen in its neighbourhood for many years. System: Direct current, 500 volts. Verdict: Death due to burns following an explosion of firedamp ignited at the liquid starter.
Sherburn Hill Colliery.	Sherburn, Durham.	April 28th .... Electric shock.	A tub left the rails crushing an unarmoured cable against a projecting catch and damaging the insulation. Deceased was sitting with his feet against the rails some little distance away. In the effort made to replace the tub the rails became live and deceased received a fatal electric shock. System: Direct current, 500 volts. Verdict: Accidental death.
Lumley No. 3 Colliery.	Fence Houses, Durham.	May 13th .... Electric shock.	Deceased was found dead in the road about 10 feet away from his motor. A fault was found in the terminal block on the conveyer motor which would have made the motor frame live had the earth connections been faulty. Examination after the accident failed, however, to reveal any defect in the latter, and the accident is therefore difficult to explain. One possible explanation appears to be that the conditions when the accident occurred and afterwards when the tests were made were not the same. A loosely-attached earth wire would explain the occurrence, or it may be that the earth connection at the time, though good, was not good enough to prevent the motor frame from assuming a potential sufficiently high above the surrounding ground (which was wet) to cause the accident. System: Three phase, 440 volts, neutral point earthed. Verdict: Accidental death
Auchengeich Colliery.	Lenzie, Lanark	June 1st...... Electric shock.	Deceased was in the habit of running his loaded tub out along the gate-road to the main road to meet the drawer. In doing so he had, on the occasion of the accident, to pass a coiled trailing cable, which though not in use, had been left connected to a gate-end switch box. Both the main cable from the surface to the gate-end box and the trailing cable were armoured. Deceased was found lying on the trailing cable alongside his loaded tub. A fault was subsequently found at a badly-made joint in the main cable, and the earth connection to the cable armouring at the surface of the mine was found to be severed. System: Three phase, 440 volts, neutral point earthed. Verdict: Accidental death.
TrimdonGrange Colliery	TrimdonGrange Durham.	June 28th .... Electric shock.	Above the working place was fixed an electric lamp, the wires being run in an iron tube at the end of which was an iron lamp shade with a thick glass outer globe to protect the lamp. Deceased was in the habit of cleaning the lamp globe nightly. He was seen to approach the lamp, but fell back immediately, afterwards calling out that he had "touched the globe." The investigation of this accident was unsatisfactory as no point of leakage could afterwards be discovered, though the insulation of the whole circuit was low. The accident occurred after a heavy shower of rain, the conditions at the time of the investigation being different from those at the time of the accident. System: Three phase, 220 volts, neutral point insulated. Verdict: Death due to electric shock.
Swalwell Colliery	Swalwell, Durham	July 8th .... Electric shock.	Deceased had been engaged in moving a pump motor to a new position in the mine. He was about to start up the motor on trial when he found that the cast-iron box containing the motor switch was live. Immediately afterwards he was seen to have hold of one of the screws for securing the switch box cover. The shock he received this time proved fatal. Subsequent examination showed a fault in an ammeter which was contained (with the motor switch) within the cast-iron box above referred to. No earth connection had been provided for the box. System: Three phase, 440 volts, neutral point earthed. Verdict: Accidental death.
Bredisholm Colliery.	Bargeddie, Lanark	November 29th Electric shock.	Deceased received the fatal electric shock in handling the coal cutter haulage rope. The latter had become live through the failure of an insulating bush round the shank of one of the prongs or pins on the side of the coal cutter for making contact with the trailing cable plug, the holes of the latter fitting over the pins of the former. There was a second fault in the circuit near the shaft bottom, at a place where the insulation had been cut by the sharp edge of a steel plate forming part of the switch gear. The two faults were on different phases. The frame of the coal cutter was earthed and also that of the switch gear at the shaft bottom, but the resistance of the latter to earth was less than in the case of the coal cutter, the latter being earthed, via the metallic sheathing of the trailing cable, which sheathing was subsequently found to have a resistance of 6 ohms. Th coal cutter frame came in this way to assume a potential above earth sufficient to give the fatal shock. System: Three phase, 550 volts, neutral point insulated. Verdict: Accidental death.
Bardykes Colliery.	Cambuslang, Lanark.	December 20th Electric shock.	Deceased was engaged in moving a coal cutter to a new position in the mine. The machine was placed on a bogie and its own power was used to transport it. It was, however, left to stand for a time, with the power switched on, beneath a break in the roof from which a small stream of water descended. The water caused a short circuit between one of the phases in the trailing cable plug and the machine frame. This combined with an earth connection which was ineffective (the earthing pin being defective) caused the machine frame to become live. Deceased touched the machine frame. System: Three phase, 500 volts, neutral point insulated. Verdict: Accidental death.

NOTE. In each of the above recorded accidents one person was killed.

ANALYSIS OF FATAL ELECTRIC SHOCK ACCIDENTS.

	Accidents.	Deaths.
Surface accidents: –		
On low-pressure three-phase system......	1	1
On medium-pressure direct-current system	1	1
Below-ground accidents: – –		
On medium-pressure three-phase systems	7	7
On medium-pressure direct-current systems	2	2
	11	11

Of the accidents on medium and low-pressure three-phase systems (eight in all), four accidents were on completely insulated systems and four on systems with the neutral point connected to earth. Brief details of each accident are given in the table on page 62.

NON-FATAL ACCIDENTS IN 1911

Underground Fires Caused by Electricity.—As in 1910, three fires were reported to have been due to electricity. The first of these took place at the Brookhill pit, near Pinxton, Derbyshire, of the Pinxton Coal Company, on April 19th. The fire occurred in a pump house which formed an inset from the downcast shaft, and the smoke was carried in-bye by the air current. The fire was, after a few hours, successfully overcome, and all the men were brought safely out of the pit. The pump was driven electrically by three-phase current at 400 volts, and though it is impossible to say definitely what caused the fire, the most likely place of origin was, in my opinion, the point at which the three-core incoming cable (a lead-sheathed paper insulated cable) was separated into its various cores for connection to the motor switch and fuses. At the Pinxton Colliery the practice had been to tape the ends of three-core paper insulated cables without sealing them. The failure of such a cable at such a point in an atmosphere which must often have been far from dry should have been anticipated, but there was a second instance of poor practice which may also have contributed to the fire. Neither the lead sheath nor armouring of the cable was connected to earth, and as one of the fuses only acted in the transformer house at bank it is most likely that the original breakdown occurred between one phase and the lead sheath of the cable. It is probable that had the lead sheath been earthed the defect would have speedily developed into a short circuit, which would have opened all three fuses and almost certainly without allowing an arc to be maintained for any considerable period of time. It is obvious that in the absence of an earth connection for metallic sheaths and coverings open sparking may continue for some time (as I think it did in this case) without causing the means provided for opening the circuit in case of a fault to operate, thus definitely introducing the risk of fire. No theory which was advanced as to the cause of the fire accords as well either with probability or with the observed facts as that given above. The roof supports were of timber, and these were quickly consumed, but the fire was successfully confined to the motor-room.

The second fire occurred at the Windsor Colliery, Abertridwr, Glamorgan, of the Windsor Steam Coal Company, on July 9th, but it is reported that little damage was done. The fire occurred in a motor room at the pit bottom, and it appears to have been due to failure of the insulation on some cables leading to the motor. No one was present at the time of the outbreak, which was very quickly overcome.

The third fire occurred at the East Parkhead Colliery, Bellshill, Lanark, of Messrs. Wilsons and Clyde Coal Company, on October 16th. The supply of current to the East Parkhead Colliery is on the direct-current concentric system at 500 volts, and the origin of the fire was traced to fusing in a four-way junction and fuse box which had been nailed to two trees on the roadside about 400 yards from the shaft bottom. It is most likely that the blowing of a fuse caused an arc to be formed between one of the fuse terminals and the side of the box, and that this arc persisted until the supporting woodwork caught fire. It is clear from the evidence of the men who were on the spot that a fuse did blow immediately before the fire was noticed, due to a fall of roof on this cable. The occurrence of this fire draws attention to the importance of ample clearance in fuse boxes. Fuse boxes should in fact be proportioned so as to contain a fuse which will open the circuit safely in any circumstance that may arise; that is to say, it is not sufficient that a fuse box should be safe if the circuit is opened under a gradually increasing flow of current, it should also be safe if the circuit is opened by the heavy flow of current which accompanies a short circuit.

Electric Shock Accidents (non-fatal).—Forty-one non-fatal electric shock accidents were reported during 1911. In many cases these accidents were trifling in their results, but in four cases the victim was unconscious for some time. In one instance, in which the Sylvester method of resuscitation was successfully used, unconsciousness continued for upwards of three-quarters of an hour. Each year instances of the successful application of methods of artificial respiration are reported, and it may in this connection be appropriate to quote a paragraph from the report of H.M. Electrical Inspector of Factories for 1911:—

"It is well known that persons having received a severe electric shock and having been rendered unconscious and apparently dead, have been in a number of instances restored by means of artificial respiration, in some cases only after the treatment has been continued for a considerable time. The success of the treatment probably depends a good deal upon the care and skill with which it is carried out. In any case the process, if continued for any length of time, as it should be if necessary, may be very laborious, particularly in the case of the Sylvester method, unless there is ample assistance at hand. In order to facilitate the treatment and render it at the same time more effective, an apparatus has been devised by Dr. K. A. Fries, of Stockholm, and has been recently introduced into this country. It has already been adopted at a number of important electrical stations. The apparatus is designed for carrying out the Sylvester method, in which the patient is placed on his back, his arms being moved up and down while pressure is brought to bear on the chest in synchronism with these movements. It is claimed that a person can operate the apparatus with one hand, leaving the other free to draw forward the tongue of the patient. It would appear, however, that the apparatus might be readily adapted to the Schäfer method, which is now generally considered by medical men to be superior, one reason being that the patient, being placed face downwards, the difficulty of the tongue blocking the air passages is obviated. In this connection it is interesting to note that a representative committee of American doctors and electrical men, who recently considered the merits of the different methods, have unanimously recommended the Schäfer method."

An Explosion of Coal Dust caused by Electricity in a Coal-crushing House at New Brancepeth Colliery.—This was an interesting instance of an explosion of coal dust alone from electric sparking. On July 6th, 1911, about 4 p.m., Mr. Peel, the agent of the colliery, when in the vicinity of the patent ovens, heard the report of an explosion, which, on investigation, proved to have come from the coal-grinding house. Inside this building there was a 25 h.p. motor, 500 volts, driving coal-grinding machinery in the form of rollers. The motor was enclosed, but not gas-tight, and stood on a platform of concrete about 6ft. above the floor. The machinery was driven by means of belts, belts being also used for conveying the ground coal up to the hopper some distance away in another building. On the opposite side of the crusher there was a coal-washer used for washing nut coal, but this had not been working for a week, consequently the immediate surroundings were probably dustier than usual, and the coal, being crushed in the dry state, produced a large amount of very fine dust. The inside of the building would be thickly coated, and a considerable amount would also be in suspension. Owing to the motor having been heating, it had been stopped for two hours that afternoon, but after having been run another half-hour the attendant again found it hot, so he came out of the building and proceeded

up some steps to have the feed cut off in order that he could run it all clear before stopping the motor, so as not to have to restart on a full load. As he was descending the wooden steps just outside the big double door of the crusher house there was an explosion of coal dust inside the house, accompanied by the report which Mr. Peel heard. Flames burst through the doorway for a distance of 6ft., and apparently also extended in an upward direction for a height of 15ft. above the motor, as some coal dust was found in a state of red glow, and was at once put out with sand. A similar portion was found glowing close to the motor. Three panes of glass were broken, but there was practically no more damage done inside, as the force of the explosion got vent at an opening in the corrugated roof. The cause of the coal-dust explosion was traced to the short circuiting of one of the armature coils, which resulted in excessive sparking, causing the ignition of the fine coal dust with which the inside of the motor casing was coated, and the force developed blew off the sheet-iron covering over the commutator end of the motor. There was evidently sufficient flame to cause an explosion of the very fine coal dust which was inside the motor-house in a state of suspension, and, as before mentioned, the flame passed outside the building followed by smoke and coal dust. The length of the flame would therefore be about 15ft. Fortunately the engineman had not re-entered the building, or he would have been severely burnt, if not more seriously injured. There was no woodwork inside the house with the exception of some fencing rails, and no signs of coking were observed. The building was about 24ft. by 20ft. by 18ft. high. A new washer was afterwards erected, and it was arranged to crush the coal after it had been washed. While these preparations were being made, however, the motor was temporarily placed outside the crusher house, in order to prevent a similar occurrence.

HOT PANEL AND HOT FLOOR BORDER SYSTEM OF HEATING.

At a recent meeting of the Junior Institution of Engineers Capt. H. Riall Sankey, R.E., M.Inst.C.E., gave the hon. member's lecture, taking for his subject, "Hot Panel and Hot Floor Border System of Heating," in which he said that the dominant feature of the new method is the use of radiant heat rather than the heating of the air. The fact is often lost sight of that the object of heating a building or room is to make people comfortable; hence it is usual to specify that the heating power and heating surface shall be sufficient to maintain the temperature of the air 5ft. from the floor at a specified temperature of, say, 63° Fah. The result has been that most of the systems hitherto adopted have been devised so as to heat the air, and radiant heat has been to a large extent neglected. It is generally conceded that for comfort, when sitting in a room without a fire, an air temperature of about 63° Fah. is needed, and in order to obtain this temperature the surfaces of ordinary radiators require to be at the fairly high temperature of, say, 150° to 180° Fah.; this temperature, however, decomposes the dust in the air, thus producing a disagreeable and characteristic smell. When radiant heat from a fire is available the air temperature can be as low as 55° Fah. or even 50° Fah., and yet the sense of comfort and warmth is greater than in the previous case. To maintain the temperature at 50° or 55° a hot-water system of heating or the like will, however, be required in many cases. Such a system, although ideal, is more costly. Now the hot-panel and hot-floor system does not unduly heat the air, as it supplies the radiant heat needed for comfort. A hot panel, Capt. Sankey explained, consists essentially of a small pipe bent backwards and forwards and imbedded in a semi-conducting composition; ½in., drawn, lap-welded steam pipe is used. The heat carrying medium, say, hot water, circulates in the tube, and the heat is conducted through the walls of the tube to the composition, through which it spreads to the surface of the panel, whence it is radiated into the room; in effect heat at a comparatively high temperature issuing from a small surface is converted into the same amount of heat at a lower temperature issuing from a large surface. A hot panel may contain more than one length of tube, in order that the flow in each length may be controlled by external valves. A hot panel can be made up in an iron frame, thus forming a detached unit similar to the ordinary radiator; or it may be built up against a wall very nearly in the thickness of the plaster. Hot borders are formed by placing drawn, lap-welded, ½in. pipes about an inch below the level of the floor, close to the walls, around the whole or part of a room, and embedding these pipes in semi-conducting composition. A hot border of any width desired, say, from 6in. to 18in., can thus be formed. Similar pipes can also be embedded along the cornices of a room. The semi-conducting composition has to be chosen with great care to obviate cracks which would otherwise be produced by the expansion and contraction of hot pipes. The various advantages of the new system were treated mathematically and a number of illustrations were given. At the conclusion of the lecture a hearty vote of thanks was passed to the lecturer, and a number of questions were put to which he replied.

NOTES ON THE BRITTLENESS TEST.*

BY M. DERIHON, ASSISTANT MANAGER, USINES G. DERIHON, LIEGE, BELGIUM.

As a matter of probable interest we communicate a number of observations collected in the course of our experience since we began to make use of the brittleness test as a standard method for our steels and forgings. Since 1904 we have used the drop weight and Frémont test piece for our tests, and we may state at once that our experience of both has been such that we have decided not to abandon them. We may say that our laboratory, though complete enough so far as mechanical tests are concerned, is not a scientific laboratory, but serves as a guide in close relation with the manufacturing department.

At present, apart from the chemical analysis, tensile tests, ball tests, &c., we have to apply the brittleness test to 80-100 tons of steel per month, bar by bar; and if we add that we leave a test piece for the brittleness test on each article of a certain class of goods that we produce, such as steering swivels and steering levers for motor-cars, it will be easily imagined that we have to test about 10,000 to 12,000 pieces every month. It will be evident that in this way we have acquired a certain experience in this kind of test, and have been enabled to form certain conclusions of a practical character.

In the first place, is the brittleness test as stringent and misleading as is generally believed? No, on the contrary we believe that after a few attempts it is possible to make all steels of good medium quality non-brittle. The whole question is merely a matter of heat treatment. Evidently, steels burdened with sulphur and phosphorus, or rotten with piping, will always remain brittle whatever one may do; but a good ordinary steel, properly treated, is nearly always non-brittle.

At the commencement of our tests, as at present, we used, in addition to certain fine, high-grade steels, a large number of open-hearth steels of various grades, the quality of which always remained approximately the same. Well, at the outset we had to reject for brittleness, 20, 30, and even 40 per cent. of the pieces tested, whereas, at the present time we find that the total number of rejections in 1911 did not exceed an average of 3 per 1,000. This results entirely from the progress which these tests have enabled us to make in the application of heat treatment to our steel forgings. Our deduction therefore is that the brittleness test has done us good service by affording us the means of arriving at such homogeneous results. Finally, can it be said that a test which gives rise to only 0·3 per cent. of rejections is incapable of being employed in practice?

Evidently one must become familiar with the impact test, and not attach undue importance to variations caused in toto by the heterogeneity of the metal. A certain grade of steel must be classed as brittle when, for instance, the resilience is shown by the test to be less than 20 kilogrammetres, and as not so when the results are more favourable; but one

* Paper read before the International Association for Testing Materials.

must not seek to grade the quality in accordance with the values obtained.

In our opinion, it is the search after this precision which has led to the large test piece being selected at the expense of the small one. The former, of much greater sectional area, evidently gives mean results which are more easily comparable and apparently more rational; but it is attended with the defect of being incapable of showing up the weaknesses of the material, which are pitilessly exposed by the small test piece assisted by micrography.

Being desirous of settling the point we selected six bars from a parcel of steel which had been rejected in consequence of the tests on Frémont test pieces, and from each bar prepared two 30 mm. by 30 mm. test pieces of the Copenhagen type, with which we obtained the following results in the Charpy apparatus:—

Bar No. 1	... 75 kilogrammetres	and	75 kilogrammetres.
,, ,, 2	... 23 ,,	,,	25 ,,
,, ,, 3	... 7·5 ,,	,,	8 ,,
,, ,, 4	... 23 ,,	,,	20·5 ,,
,, ,, 5	... 41·7 ,,	,,	41·7 ,,
,, ,, 6	... 75 ,,	,,	75 ,,

If these bars were to be rejected on account of giving values below 20 kilogrammetres, then only the bar No. 3 would be thrown out, and perhaps No. 4 as well. However, they were all bad since, independently of the Frémont test, which had condemned them, micrographical examination revealed the presence of serious pipings. Hence, we do not think it rash to conclude that, without the Frémont test, we should have been led to employ steels of bad quality.

The large test piece is evidently not always optimistic, and reveals certain causes of brittleness; but in our opinion it does not always expose them and with the same rigour as the small test piece. But since the causes of brittleness in steel are often local, it would seem preferable to isolate them rather than conceal them in the mass of the metal. So far as concerns ourselves, one serious reproach to the 30 mm. by 30 mm. test piece is that it cannot be used in the case of the forgings we produce, owing to its large size.

We are well aware that the Copenhagen Congress recommends in such cases the use of the 10 mm. by 10 mm. test piece, nicked half-way through; but we must confess we should have preferred to keep to the Frémont type of test piece, 10 mm. by 8 mm. with a 1 mm. nick. In the first place, being flat, this test piece presents the advantage of enabling the direction of the fibres of the metal to be traced. It is also less expensive and less difficult, the small hole terminating the nick of the 10 mm by 10 mm. test piece being difficult to make readily; and we are acquainted with several laboratories in which the use of this nick has been abandoned on account of the difficulties experienced in the shop.

As for the sharp edges of the nick, we must confess that we have never troubled about them. On no occasion, in the large number of tests performed, have we found any of the unfavourable results to be due to the nick. When a test piece breaks under a low strain, it is because the steel is brittle; and since we have now only 0·3 per cent. of rejections, we think these minor points may be neglected.

Finally, although we have no desire to reopen the discussion as to which apparatus should be used for the impact test, we take the liberty of expressing our opinion, which is based, not on scientific considerations, but on personal experience of forging and stamping machines. Frémont claims that his drop weight, or similar appliance, is alone capable of revealing brittleness in all cases. In our opinion he is right, and for the following reason. We believe in the drop weight, because our forgings are made under the steam hammer and drop hammer; and we find that the velocity of the impact and the quantity of the mass receiving the impact are of prime importance. The importance of these two factors is such that it is they which practically limit the work of our drop hammers.

The matrices, being made of very hard, and more or less brittle steel, will not stand, but are constantly breaking, if the height of fall be too great or the impact is too sharp. On this account we have therefore been compelled to reduce the height of fall, increasing the weight of the falling mass, and arranging under the anvil bed a foundation of wooden baulks, so as to take up the impact elastically. This, however, is accomplished at the expense of the useful effect, since a weight of 500 kilos. falling from a height of 1 metre, is more economical than one of 1,000 kilos. falling a height of 2 metres.

We believe therefore, as Frémont has said, that an apparatus which does not give sufficient velocity of impact or in which the anvil bed is not sufficiently heavy, cannot reveal the brittleness of the test metal in all cases. The conclusion we draw from this is that, as was wisely decided by the Copenhagen Congress, the Congress should abstain from prescribing any special type of apparatus for performing the impact test; but that it should direct attention to the importance, with regard to the results, of the velocity of the impact and the mass of the anvil bed receiving same.

The author has adopted the brittleness test as the general test used in passing material at his works. His experience leads him to maintain that this test is less severe than is generally believed, and it enables non-brittle steels to be readily obtained by a suitable process of graining. He prefers the small test piece of the Frémont type, which reveals local defects forming the germ of future cracks. He also attributes high importance to the velocity of impact and to the anvil bed, both of which should be considerable if the test be really desired to reveal the brittleness of the material.

NOZZLES FOR STEAM OR GAS TURBINES.

THE accompanying illustrations show an arrangement designed and patented by Messrs. Brown, Boveri, & Co., Baden, Switzerland, of nozzles for steam or gas turbines, in which the nozzle is formed in two parts, one of which contains nozzle passages in one of its faces, while the other is adapted to close these passages. The parts are maintained in contact with one another and in the required position in the turbine casing on the one side by an abutment on the casing and on the other by a caulking strip. Fig. 1 shows in section the assembled nozzle parts in a turbine. Fig. 2 shows views of

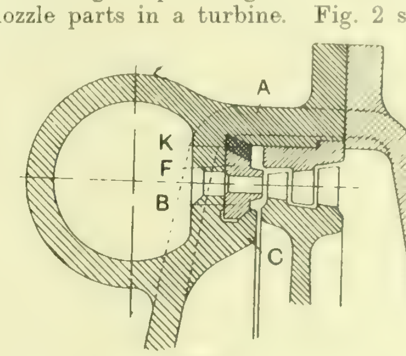


Fig. 1

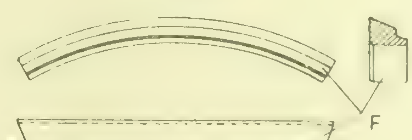


Fig. 2.

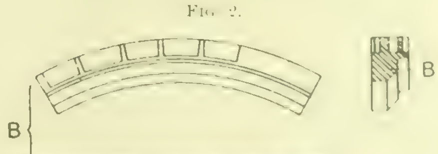


Fig. 3.

Nozzles for Steam or Gas Turbines.

the top part of the nozzle shown in Fig. 1, and Fig. 3 views of the lower part of the nozzle shown in Fig. 1. The turbine casing A is provided with a suitable abutment C. Against this abutment is placed the lower part B of the nozzle as shown in Fig. 1. The upper part F of the nozzle is then placed in position and a caulking strip K inserted between this upper part and the turbine casing A. In this manner the two parts F and B of the nozzle are pressed together and against the abutment C, so that the nozzle parts are secured in correct position in the turbine casing A.

THE "PARAGON" INTERNAL-COMBUSTION ENGINE.

In connection with the development of the "Paragon" system of electric propulsion of vehicles and ships, Mr. W. P. Durtnall, in conjunction with Mr. H. B. Deane and Mr. G. T. Bowles, has designed and patented a new cycle for internal-combustion engines, a description of which appeared in "The Railway Times" of December 28th last. During his investigations with the "Paragon" system of electrical transmission Mr. Durtnall experienced certain difficulties as regards the

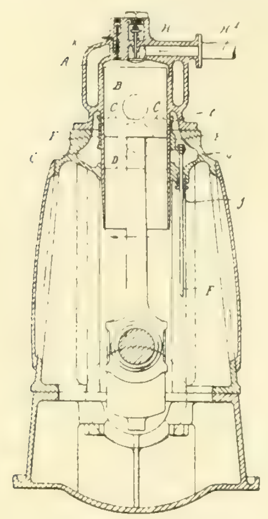


FIG. 1.—DIAGRAMMATIC SECTION OF 2-CYCLE "PARAGON" ENGINE.

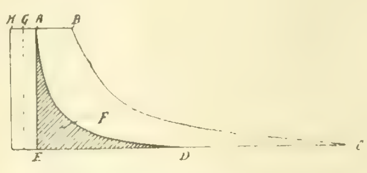


FIG. 2.—PRESSURE-VOLUME DIAGRAM 2-CYCLE "PARAGON" ENGINE.

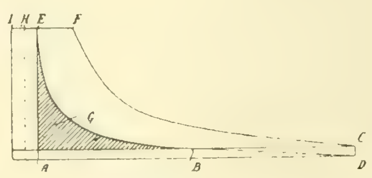


FIG. 3.—PRESSURE-VOLUME DIAGRAM 4-CYCLE "PARAGON" ENGINE.

application of the Diesel engine to railway operation. One of the most prominent was noise from exhaust gases, and another was the amount and weight of water to be carried for the purpose of cooling the cylinders, and it was with a view to overcome these objections that led to the design of the engine under notice.

Fig. 1 is a diagrammatic section of the "Paragon" 2-cycle internal-combustion engine designed to run at constant revolution speed on either crude or residue oil, paraffin, or other by-products of coal distillation. Assuming that it is arranged to use residue oil as fuel, as in the case of the Diesel engine, the compression pressure would be about 500lbs. per square inch, and in Fig. 1 it will be seen that the piston B is at the top of the compression stroke, and it may be assumed that a pressure of 500lbs. exists in the compression space at a temperature of approximately 1,000° Fah. The crank is just turning the top or inner centre, and at this point the fuel is forced into the compression space, by means of a force pump driven by the engine. The fuel immediately ignites by reason of the high temperature of the compressed air which supports its combustion. The rise in temperature would cause a rise in pressure above the 500lbs. got by the compression of the air, but at this point the piston is travelling in a downward direction, thus increasing the volume of the compression space, so that the working pressure does not materially rise higher than the compression pressure.

The admission of fuel is cut off early in the working or down stroke; the piston, however, proceeds on this working stroke, passes the exhaust ports C (which are, however, closed by the exhaust sleeve valve E), so that the pressure is expanded down to almost that of the atmosphere when the piston arrives at the end of the working stroke at D. It is important to bear in mind, also, that the temperature is also very low at this last point, so that when the operating rod F now opens the exhaust sleeve valve E, the pressure in the cylinder being expanded below the pressure kept up in the supply pipe H^1 the air scavenging valve H opens and the scavenging air rushes into the cylinder at this point, and sweeps out most of the products of combustion; at the same time, it charges the cylinder with a fresh portion of air for the next down or working stroke.

The crank turning the outer dead-centre, the piston moves from D up to the ports shown at C, and so "mechanically" clearing out a certain amount of the burnt gases into the receiver G, the piston runs past the ports C, and so automatically closes them. The pressure then rises above the pressure in the pipe H^1, so that valve H closes, and the cylinder becomes sealed, the compression pressure running up to 500lbs. again, and the cycle of operations is repeated on the following down stroke.

Fig. 2 shows a pressure-volume diagram of the 2-cycle method of operation. The stroke of the engine is shown from E to C, the compression space in a relative Diesel 2-cycle engine is shown from E to H, the compression space in the "Paragon" 2-cycle engine is shown at the dotted line G, the work of compression is shown at F, compression only beginning at D as the piston runs past the exhaust ports C (Fig. 1), the compression pressure running up to A (Fig. 2), and at which point the piston is at E or the inner end of the compression stroke. The pump then admits fuel as the piston proceeds from the line A to B, at which point the fuel is cut off, and the expansion of the pressure and heat begins, and runs right down to approximately the pressure of the atmosphere at C. The exhaust sleeve valve here opens the ports C (Fig. 1), the piston travels back to D (Fig. 2), compression begins and runs up again to A, and so every down stroke is a working stroke. Consequently the weight of this engine for a given output is low, which is important in railway transportation from many aspects. At the same time, the exhaust pressure being at about that of the atmosphere, there is really no noise from this source.

Fig. 3 shows the diagram of the 4-cycle method of operation. The stroke is from A to C, the compression space of an ordinary engine is from A to I, the compression space in

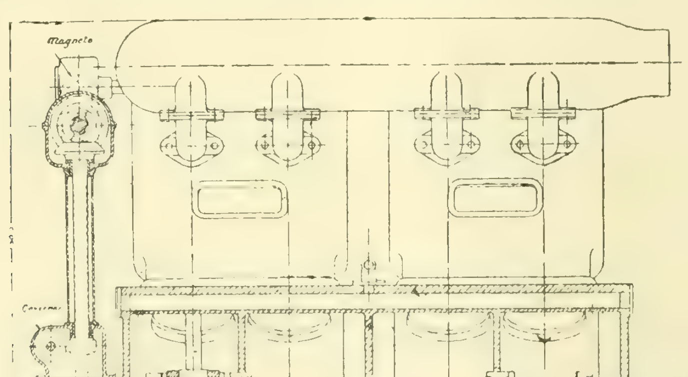


FIG. 4.

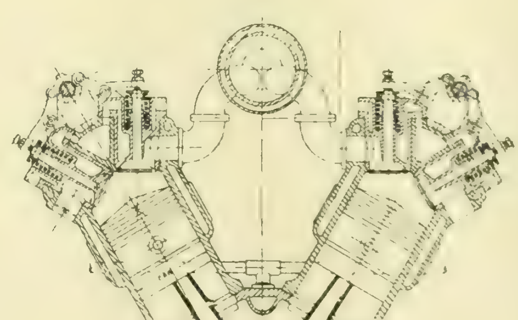


FIG. 5.

"PARAGON" CONSTANT-VOLUME ENGINE FOR LARGE RAIL CAR.

the "Paragon" 4-cycle engine is from A to H, the work of compression is shown at G, and assuming that residue oil is used, then the compression is, say, 500lbs., and shown at E. Assuming that the piston is starting on the outward or suction stroke, the piston runs from A to B. At this point the air induction valve is mechanically closed, the piston runs out to C, the pressure in the cylinder (which was at atmospheric pressure in the cylinder B) falls below that of the atmosphere to the point shown at D. This difference of pressure acting on the outside of the piston, owing to the pressure of the atmosphere, tends to arrest the momentum of the working parts (piston and rod), thereby reducing the pressure on the bearings. When the piston reaches the end of the induction stroke at C, the crank turns the outer dead-centre, and the difference of pressure outside and inside the cylinder acts on the piston and accelerates it to B, when the pressure is balanced. The piston moves back to A, so that the air is compressed up to the full compression pressure. The crank turns the inner dead-centre, the fuel is forced in from E to F. Expansion then begins and runs right through to C, the crank turns the end of this stroke, the exhaust valve is opened, and remains open while the piston runs from C back to A, when the maximum amount of products of combustion are swept out, owing to the reduced space at the compression chamber, as will be seen by the lines H and I. The cycle is then repeated.

Owing to the reduction in the wall area in the compression space of this engine, it is claimed that fewer heat units get away to the circulating water, and, owing to the much longer expansion of the volume of charge, as is shown above, the heat of the fuel is utilised in the production of work, so there is a great reduction in the exhaust heat losses found in all other internal-combustion engines. Consequently there is a much higher thermal efficiency in this "Paragon" engine. It has been estimated that from 15 to 25 per cent. more work for the same amount of fuel is possible, according to working conditions. This cycle of operation is also applicable to what are termed constant volume internal-combustion engines.

Figs. 4 and 5 show a form of the "Paragon" constant-volume engine designed for a large rail car in which the "Paragon polyphase alternating-current system of power transmission is to be used. The engine shown will develop about 230 b.h.p. at 900 revs. per minute. The cylinders have a bore of 260 mm. and a stroke of 200 mm. The engine is 2,100 mm. long, 1,000 mm. wide, and stands 1,730 mm. high. There is no flywheel (the necessary flywheel effect being obtained by the electrical generator); it has eight cylinders, and is constructed on the V type, with overhead operating valves and cam shafts. The engine is fitted with a paraffin carburetter and high-tension magneto ignition, is water-cooled, and the crank chamber is ventilated by means of a duct cast round the top half of the crank case, and this is connected by means of pipes to the carburetter. The main bearings are force-lubricated by means of a geared pump, and the oil is then sent through the hollow crank shaft to the large connecting rods. Although in this application the engine will be started electrically, it can be also started by means of a small compressed-air plant, say, from the brake reservoirs. The paraffin consumption is estimated at ·45lb. per brake horse-power hour. The engine is fitted with a sensitive but powerful speed governor. Owing to the longer period of time for the burning of the volume of fuel, practically complete combustion takes place, so that absence of smoke or smell will be a noticeable feature during its operation.

Copper Wire Tables.—The United States Bureau of Standards has issued a circular which discusses the results of work recently completed at the Bureau on the temperature coefficient and the conductivity of copper, as well as previous standard values, and gives a history of wire gauges, showing that the trend of practice is toward expressing diameter directly in decimal fractions of an inch. There are 15 tables, including complete reference tables for standard annealed copper, American wire gauge, both in English and in metric units; and similar abbreviated "working tables." There are also tables for bare concentric cables of standard annealed copper and for hard-drawn aluminium wire. The tables also include comparisons of wire gauges, and tables of temperature reductions, with complete explanations.

EFFECT OF ALUMINA IN BLASTFURNACE SLAGS.*

BY J. E. JOHNSON, JUN.

THE subject of blastfurnace slag is one which has had much consideration, particularly from the scientific standpoint, and several years ago technical literature contained many learned discussions on the oxygen ratio of the acids and the bases, all on the assumption that acids and bases must be present in a ratio depending on molecular weight and chemical valency. Much work has also been done, sometimes in conjunction with the former, on the total heat and the temperature of initial fusion or softening of various slags. A wider knowledge of the blastfurnace now enables us to say that for practical purposes this work has been of almost no value.

It is now generally admitted that on the physical side the important point of a given slag is neither its total heat of fusion nor its softening point, but its free-running temperature, since this is the critical temperature of the furnace. This temperature bears no definite relation to the softening temperature, as determined by Seger cones, for instance, because some slags melt relatively like ice, with a very short viscous range, while others melt relatively like tar, with a very long viscous range. In one the difference between the softening and the free-running temperature may be very small, as little as 100° Fah., while in another this difference may easily be 200° or 300°. The importance of this difference is so great in practice as to destroy completely the value of exhaustive investigations, even such as those of O. Boudouard, published a few years ago.

It may not be amiss at this point to call attention to the excellent suggestion of Woolsey McA. Johnson, made several years ago, for determining the temperature at which different slags have the same practical fusibility. This suggestion was briefly to make experiments in a small electrically-heated furnace, the bottom of which was a carbon slab with a small round hole through it. The temperature at which different slags would flow through this hole would furnish accurate information as to their relative practical fusibility. To determine the proper size of the hole through the carbon block, I offer the further suggestion that the temperature of the slag flowing over the cinder dam in standard furnace practice be taken when the slag was about of normal composition. Then put some of this slag in the experimental furnace and heat it to the temperature observed. A few trials would determine the size of the hole through which it would flow at this temperature. This size of hole could then be used in future experiments with the certainty of obtaining results comparable with actual practice. Investigations along these lines would be of real interest and value to furnacemen.

When we come to the chemical side of the question we may as well dismiss the obscuration which comes from the introduction of oxygen ratios and other abstruse theoretical considerations, and admit frankly that experiment on the furnace itself is the only safe foundation for practice or for a useful theory. I am moved to lay stress on this point because in years past I was greatly puzzled and befogged by some of the older school of furnacemen, who emphasized the mysterious nature and difficulty of making slag calculations, the fact being that, given the materials to be used and the slag to be produced, the college student who could not be taught in a day to make the calculations would have a poor chance of ultimate usefulness. The omission or concealment of the fact that the slag to be produced was known only by experiment and experience with the furnace itself caused my mystification, and I therefore emphasize it here.

The object to be sought may be briefly stated as follows: Given the materials to be used and the kind of iron to be made, to ascertain the slag which will produce the result with the least cost for coke and for flux, and will permit the greatest output. The three desiderata come in the order given.

We may in this discussion omit consideration of charcoal practice, because the slag question is of minimum importance in that field, and the field itself is of minimum importance in the iron industry. Coming then to normal coke practice and remembering that generally the lowest fuel consumption is obtained with the lowest critical temperature, the object desired may be stated more definitely as the production of the

* Paper presented at the Cleveland meeting of the American Institute of Mining Engineers.

most fusible slag that will give the necessary desulphurisation of the iron. This statement is perhaps subject to certain limitations from the fact that there are circumstances in which it is necessary to raise the critical temperature in order to enable the iron to absorb a large quantity of silicon. The extent of this limitation I am not able to state, but we will return to this subject later.

It is necessary to remember that while the effect of lime is to increase the basicity of slag and facilitate the removal of sulphur, its use is subject to grave limitations, for two reasons: (1) The lime being generally the major ingredient of the slag, to increase the percentage of the lime in the slag involves a more than proportional increase in the slag volume; for instance, to increase the percentage from 50 to 55 requires an increase of more than 10 per cent. of the weight of the slag in the lime, or about twice as much in limestone. (2) The addition of lime raises the fusion point of the slag very rapidly.

The desulphurising effect of the slag is proportional, not only to its basicity, but also to its fluidity in an almost equal degree, so that while increased lime *per se* has a desulphurising influence, this is, to an increasing extent, neutralised and finally reversed completely by its decreased physical activity. This is well shown in basic practice, in which the highest sulphur iron is made, not with deficient lime, but with an excess (due to a change in ore or the like) so great that the heat available is unable to bring the very refractory slag to the free-running condition.

In further illustration of the point, there are two distinct methods of making this kind of iron. The first consists in running on a very calcareous slag, with which the silicon in the iron is kept down by the basicity of the slag in spite of the high temperature necessary to keep the latter fluid. The second consists in maintaining a slag of only moderate basicity and much lower fusion temperature and keeping down the silicon by carrying a heavy ore burden, which, of course, can easily be done with the lower critical temperature. Furnaces running on the first plan always require more coke for basic than for foundry iron, while those running on the second plan use less than for foundry iron.

It seems to me practically certain, therefore, that there is a considerable range of lime content in the slag for given conditions, in which the desulphurisation of the iron is not appreciably affected, while the coke consumption necessarily rises with the increase in the fusion temperature consequent on the higher lime ratio, as well as the increased slag volume. In the case of foundry iron, the increase of lime may be positively detrimental because of the reduction of silicon in the iron. I have recently been informed of several cases in which the lime had habitually been carried too high, because this action was not understood. These cases of bad furnace operation show the importance of this subject.

In all theoretical slag calculations the quantity of magnesia is multiplied by 1·4 to put it on the same basis as the lime, which, from the point of view of the oxygen ratio and molecular weights, is perfectly correct. Practically, however, this does not work out. Furnacemen using a limestone with a variable content of magnesia have told me that careful observation had failed to show any difference whatever on the furnace whether the magnesia was high or low, and I have seen a furnace using half calcite and half dolomite, the calcite being relatively impure and the dolomite very pure, put on all dolomite, which should have made the slag excessively basic, on the basis of molecular weight, but which as a matter of fact showed no observable change. The truth seems to be that magnesia is less active chemically than lime in about the same proportion that its molecular weight is less.

An interesting proof of its small chemical activity is supplied by the manufacture of caustic soda from the carbonate. Quicklime is added to the carbonate solution and takes up the carbon dioxide from the soda; for this purpose magnesia is found to be perfectly inert and worthless. Sir Lowthian Bell's opinion that magnesia was so inert as to be useless for the removal of sulphur in the blastfurnace is well known, but this opinion is no more borne out by practice than that giving it a greater value than lime, the truth appearing to be that for furnace purposes, in all ordinary proportions, one is about as effective as the other. It is very necessary, however, to recognise that the addition of a certain amount of magnesia has a marked effect in lowering the fusion temperature of the slag, and is therefore of great use where calcareous slags are required, particularly in the manufacture of basic iron. For practical purposes lime and magnesia may be considered as being of equal value, and hereafter in this paper "lime" will be used to mean the sum of lime and magnesia.

The foregoing portion of this paper contains nothing essentially new and is intended as an introduction to the remaining portion, the substance of which seems to have been unknown to most of the furnacemen with whom I have discussed the subject. The effect of alumina has been the subject of much discussion; some regard it as an acid, others as a base, while a few declare it can be made to act as a base or an acid almost at will. It has seemed to me that under such circumstances the probability was that its action was neither acid or basic, but was perfectly neutral, simply a diluent affecting the viscosity of the slag to some extent, but, with a given ratio of lime to silica, not affecting its chemical nature at all. This conception of a given constituent affecting the physical but not the chemical properties of slag, in which two kinds of properties are so closely interwoven, is difficult at first sight, but I have illustrated it for myself as follows: If we had an ordinary acid, such as hydrochloric acid, in one beaker, and a solution of caustic alkali in another, we could mix the two in any proportions and each addition of one or the other would correspond to the change in the acidity or basicity of the resultant solution, but if we added a considerable quantity of molasses we should alter its viscosity and its "free-running temperature," without affecting its chemical properties in any way. The illustration is a homely one, but in my opinion the case is precisely parallel to that of slags.

For several years the range of alumina in slag of which I had knowledge was so limited that I could not prove this contention, but very recently a furnaceman gave me complete information of a remarkable series of experiments he had carried out, in which the alumina in the slag had been as high as 39·5 per cent., with silica as low as 21 per cent. on individual flushes, and averaging for an entire day SiO_2, 24·7; Al_2O_3, 36·0 per cent. The iron made was good Bessemer iron, about 2 per cent. of silicon, with sulphur about 0·023 per cent. With this let us compare standard Lake ore practice, on basic iron, running about Al_2O_3, 13·5; SiO_2, 33 per cent.; and Virginia practice on the same iron, Al_2O_3, 6·5; SiO_2 36 per cent.

It is unfortunate that the experimental run was on Bessemer instead of basic iron. The records of other days which show basic iron made are not so complete, but they indicate only a small difference in the slag; that shown, of course, being an increase in lime. The coke consumption of this slag was not materially different from what it was in standard practice; the slags were free flowing, and did not have a noticeably higher fusion temperature than ordinary.

Here, then, we have three cases, in all of which the coke is of about the same sulphur content, the desulphurisation of the iron is the same, the coke consumption is no more different than would be accounted for by the different kinds of ore. The only difference of importance is the silicon in the iron, which is not sufficient to require a very great change in the slag composition. We will refer to this condition later.

The amount of lime in these slags can be calculated, but it is necessary to remember that there is a small quantity of neutral material, CaS, FeO, MnO, &c., which may be taken at 3·5 per cent. in all cases as a close approximation to good practice. Following this procedure, the results shown in the first four columns of Table I. are obtained: —

TABLE I.—*Composition of Slags.*

	1	2	3	4	5	6	7
	Al_2O_3 per cent.	SiO_2 per cent.	CaO by Difference per cent.	Neutral Substances per cent.	Ratio CaO / Al_2O_3 + SiO_2	Ratio CaO + Al_2O_3 / SiO_2	Ratio CaO / SiO_2
Virginia practice.........	6·5	36·0	54·0	3·5	1·27	1·68	1·50
Lake-ore practice	13·5	33·0	50·0	3·5	1·08	1·92	1·51
Special experiment......	36·0	24·7	36·8	3·5	0·59	2·90	1·44

Columns 5 and 6 present the ratios of lime to silica + alumina, and lime + alumina to silica. These ratios change from 1·27 to 0·59 in the first case, and from 1·68 to 2·90 in the second case. No one can hope to show any relations between

these ratios that can bear in any intelligible way on the variation of the alumina content.

Column 7, however, shows the ratio of the lime to the silica, which is virtually a constant throughout. The result in the experiment is the lowest, and corresponds to the higher silicon in the iron. If the lime were increased in this latter case about 5 per cent. of its own weight, this slag would then have identically the same ratio as the others, and would be just about as much "limier" as would permit the production of basic iron by the addition of a little more burden.

It may be claimed in opposition that the analyses chosen as representative of Virginia and Lake ore practice have been taken with the object of showing the result desired rather than representing the typical slags. For the Virginia practice this certainly is not true, and if there be any error in the slag analysis for Lake ore, I do not know how to better it. Certainly no correction that could be made would fail to leave the lime-silica ratio infinitely nearer a constant than either of the others.

It may be well to reiterate here that such a comparison is only useful in the case of furnaces on a comparable basis in other respects; that is to say, working for the same degree of desulphurisation and the same silicon, and using materials of about the same sulphur content. The question of the slag volume also enters here, and the question whether a given slag volume is as efficacious in the removal of sulphur when the alumina is high as when it is low. We know that if the slag exceeds a certain content of sulphur in ordinary practice, the desulphurisation of the iron will be incomplete, and if the alumina be simply a diluent the effectiveness of the slag might be diminished in proportion as the percentage of the alumina rose.

In spite of this theoretical consideration, the sulphur in the slags in the high-alumina experiments mentioned ran about 1·75 per cent., with perfectly satisfactory desulphurisation, while the relative slag volume was little, if any, higher with alumina approaching 40 per cent. than with normal alumina.

On foundry irons the ratio of lime to silica is, of course, lower than on basic. In Virginia practice the typical analysis would be about: Al_2O_3, 7; SiO_2, 41; CaO, 48·5; neutral substances, 3·5 per cent., giving a lime-silica ratio of 1·2 instead of 1·5 on basic iron. A recent opportunity of discussing this subject with many furnacemen in all parts of the country has shown that virtually all slags for foundry iron have a lime-silica ratio of between 1·2 and 1·4. Foundry iron practice is so much less definite than basic that the same exactness of ratio is hardly to be expected, and data are not at hand to determine a correct ratio definitely.

There seems to be a fairly well-defined opinion among the best-informed furnacemen that alumina has the effect of making the slag viscous and stringy in a certain range, beginning about 16, reaching a maximum about 20, and disappearing between 25 and 30 per cent. The data at hand do not permit of a definite statement on the subject, because the lime-silica ratio is not known for a sufficient number of cases, and if high alumina be coupled with a higher than normal lime-silica ratio, it is not fair to blame the alumina any more than the high lime for the result.

One case is on record in which the high alumina was coupled with excessively bad results, but it was also coupled with an extremely high-sulphur coke, which compelled the use of very high lime, which resulted in an infusible slag. In such a case the high alumina may do no more than render stringy a slag that would be troublesome in any event. A question of this character can only be properly settled by the use of an accurate pyrometer for determining the temperature at which different slags become free running. The perfection of an accurate optical pyrometer which can easily be used to determine the temperature of the slag close to the furnace would make the investigation relatively easy.

The utility of such knowledge lies in enabling us to determine in advance the slag which will give satisfactory results in practice when a change in the materials used causes the alumina to exceed the ordinary limits. The decreasing grade of the ores available must result in the increasing use of many ores higher in alumina than those of present practice. If the laws governing its action are not known, bad results are bound to follow.

A furnaceman recently told me of a case in which the alumina had been regarded as an acid, and the slag had been calculated to give the same ratio of lime to silica + alumina as in standard practice, with the result that the furnace had been badly "bunged up" with lime. Several furnacemen with whom I have talked had realised that alumina could not be properly regarded in this way, but only two have made definite statements that they regarded it as a neutral substance, and only one had reached the conclusion that a definite lime-silica ratio was the object to be attained. This was J. H. Frantz, general manager, Columbus Iron and Steel Company. Several years ago he had reached the opinion here maintained, and had prepared a table giving a lime-silica ratio of 1·5 with percentages of alumina varying from 8 to 30 per cent. He also told me that this view had been published several years ago, but he did not remember the name of the publication or of the author.

In conclusion, it seems worth while to point out that the increased viscosity accompanying high alumina may be of benefit in making foundry iron. This was a subject to which both Mr. Frantz and I independently had given some consideration for several years. That iron will not take up much silicon except at a relatively high temperature is well known, and as its melting temperature is relatively low, its tendency is to run down out of the region in which it can absorb silicon into the crucible. The fusion temperature of slag is much higher than that of iron, and, being more viscous, it acts as a retardant on the iron and always delays its descent so that it can acquire the necessary temperature.

A too fusible slag does not perform this function properly, and I have personally seen a case in which no reasonable reduction of burden would raise the silicon to ordinary foundry limits, but in which this was easily done by increasing the lime considerably beyond that necessary for desulphurisation in spite of the desiliconising influence of the more basic slag. For the same reason it is more difficult to make foundry iron when enough magnesia is present to increase the fluidity of the slag. Now if alumina increases the viscosity of the slag without the accompanying desiliconising influence of the limier slags of the same free-running temperature, then the introduction of the silicon into the iron should be facilitated by high alumina. Mr. Frantz is of the opinion that this is true to some extent. My own experience does not cover the point.

METAL QUOTATIONS.

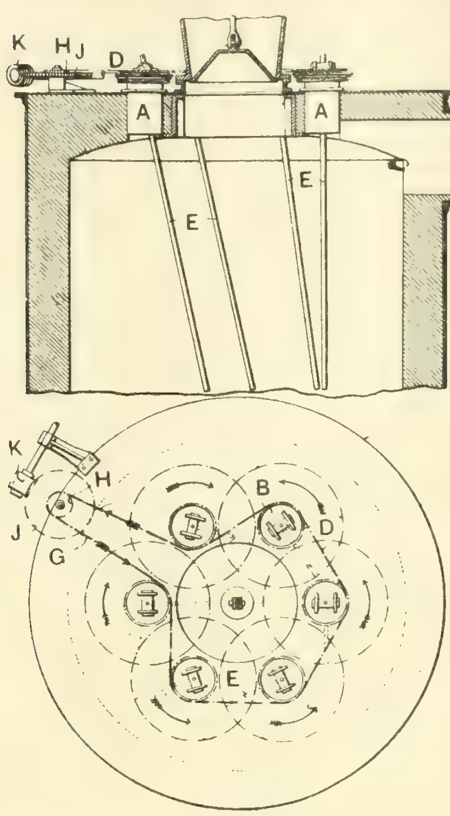
TUESDAY, JANUARY 14TH.

Aluminium ingot		95/- per cwt.
,, wire, according to sizes, &c.	from	112/- ,,
,, sheets ,, ,,	,,	120/- ,,
Antimony	£38/-/- to	£40/-/- per ton.
Brass, rolled		9d. per lb.
,, tubes (brazed)		$10\frac{7}{8}$d.
,, ,, (solid drawn)		$9\frac{1}{2}$d.
,, ,, wire		9d.
Copper, Standard		£70/15/- per ton.
Iron, Cleveland		66/3 ,,
,, Scotch		72/3 ,,
Lead, English		£17/10/- ,,
,, Foreign (soft)		£17/-/- ,,
Mica (in original cases), small		6d. to 3/- per lb.
,, ,, ,, medium		3/6 to 6/- ,,
,, ,, ,, large		7/6 to 11/- ,,
Quicksilver		£7/15/6 per bottle
Silver		$29\frac{1}{16}$d. per oz.
Spelter		£26/5/- per ton.
Tin, block		£226/10/- ,,
Tin plates		$15/1\frac{1}{2}$,,
Zinc sheets (Silesian)		£29/7/6 ,,
,, (Stettin; Vieille Montagne)		£30/5/- ,,

Hydraulic Pumping Plant for Cardiff Docks.—The Hydraulic Engineering Company, Ltd., Chester, have recently been entrusted with an order by the Cardiff Railway Company for four sets of vertical triple-expansion hydraulic pumping engines for a new extension at the Cardiff Docks. These engines will be similar to those installed at the Grosvenor Road Station of the London Hydraulic Power Company, and will be capable of delivering 450 galls. of water per minute against an accumulator pressure of 850lbs. per square inch. Their design will be most up to date in all respects, and a high steam efficiency is guaranteed. Steam will be supplied by Babcock & Wilcox boilers at a pressure of 180lbs. per square inch.

REVOLVING POKERS FOR GAS PRODUCERS.

In gas producers using bituminous or other similar fuel it is necessary for the successful operation of the apparatus to provide some arrangement for agitating the fuel in order to avoid caking or clinkering. An arrangement for this purpose has recently been patented by The Dowson & Mason Gas Plant Company, Ltd., Alma Works, Levenshulme, Manchester, in conjunction with Mr. J. Cunningham. In this construction there are annularly disposed in the top of the producer and around the usual central feeding hopper, a



FIGS. 1 AND 2.
REVOLVING POKERS FOR GAS PRODUCERS.

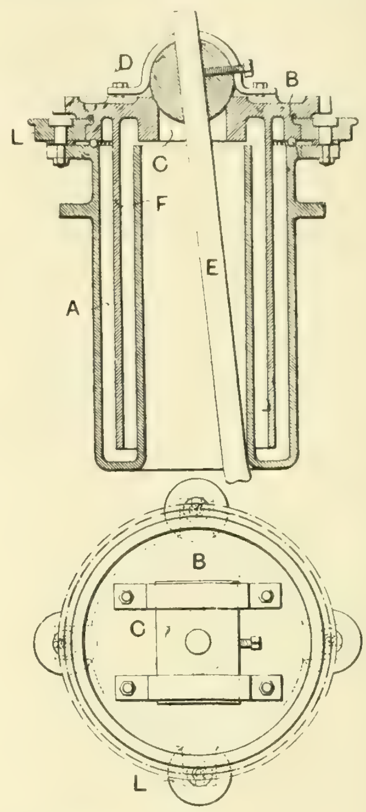


FIG. 3.

series of rotatable heads, preferably water-luted, and having adjustable cylindrical parts carrying pokers, which may be water-cooled, and which project more or less into the fuel. The heads are rotated and with them the pokers by an endless chain gearing with sprocket teeth on the periphery of each head, the chain also gearing with a pinion rotated in turn by gearing from any suitable source of power. The adjustable cylindrical parts permit of the pokers being set at various angles, so that when the pokers are rotated their points may describe circles of any desired and various diameters.

Fig. 1 is a vertical section of parts of a gas producer sufficient to show the arrangement. Fig. 2 is a plan showing diagrammatically the means used for rotating the poker-carrying heads. Fig. 3 shows respectively a vertical section and a plan to an enlarged scale of one of the water-luted heads. The producer consists of the usual firebrick-lined metal casing having a central feeding hopper and an outlet for the gas produced. Through the top of the producer and annularly disposed around the feeding hopper there are formed a series of apertures in each of which there is carried an annular chamber A, the chambers being supported in the apertures by flanges thereon resting on the top of the producer and bolted thereto. Over each chamber A there extends a head B resting on a ball bearing carried on the upper surface of a flange surrounding the upper end of the chamber A. An aperture C is formed through the central part of each head B, this aperture being closed by a cylinder D held in place by straps, the ends of which are bolted to the head B. A poker E extends through each cylinder D and projects to any desired extent into the fuel within the producer, being held in the desired position by a pinching screw. The pokers E may be adjusted in angle within limits determined by the internal diameter of the annular chamber A upon loosening the straps and setting each poker at the desired angle, whereupon the straps being again secured the parts are held in the desired position. From the under side of each head B a cylindrical flange F projects into the annular chamber A, and on the chamber being filled with water the head is luted and leakage of gas prevented. Sprocket teeth are formed on the periphery of each head B, and an endless sprocket chain is made to gear with the sprocket teeth, as shown by the chain line G (Fig. 2). The sprocket chain also gears with a pinion H fixed to a worm-wheel J on a stud secured in the top of the producer and rotated by a worm K driven through gearing (not shown) from any suitable source of power, so that on rotation of the shaft the heads B are all made to revolve, displacement of the heads being prevented by guide rollers L carried on studs secured in the flange on the chamber A. The rotation of the heads B causes the pokers E which they carry to be also rotated, their lower ends describing the circles indicated by the chain lines (Fig. 2). This rotation of the pokers effectively keeps the fuel from caking or clinkering, so that thorough gasification of the fuel is ensured. The pokers may be water-cooled if desired.

PHOSPHOR-BRONZE FORMULAS.

The composition of various alloys of phosphor-bronze ordinarily employed in France was given in a recent issue of "La Fonderie Modern." They are classified under three heads, namely, tin, zinc, and lead phosphor-bronzes. Under the head of tin bronzes the following alloys are given: For a tough ductile alloy: Copper, 90 per cent.; tin, 10 per cent.; and phosphorus, 0·5 per cent. For water and steam pressures: Copper, 87·5 per cent.; tin, 12·5 per cent.; and phosphorus, 0·4 per cent. Three other alloys are given for use where a very hard metal is required, the tin content being 14, 16, and 18 per cent. respectively, and the phosphorus in each case, 0·4 per cent.; the remainder of the alloy consists of copper.

For hydraulic pistons the following alloy is recommended: Copper, 83 per cent.; tin, 11 per cent.; zinc, 6 per cent.; and phosphorus, 0·4 per cent. For bearings the three following alloys are given: (1) Copper, 81 per cent.; tin, 15 per cent.; zinc, 4 per cent.; and phosphorus, 0·35 per cent. (2) Copper, 74 per cent.; tin, 12 per cent.; zinc, 14 per cent.; and phosphorus, 0·3 per cent. (3) Copper, 72 per cent.; tin, 11 per cent.; zinc, 17 per cent.; and phosphorus, 0·25 per cent.

The lead series include four formulæ, all of which are suitable for bearing purposes, namely: (1) Copper, 86 per cent.; tin, 8 per cent.; lead, 6 per cent.; and phosphorus, 0·5 per cent. (2) Copper, 83 per cent.; tin, 11 per cent.; lead, 6 per cent.; and phosphorus, 0·4 per cent. (3) Copper, 83 per cent.; tin, 5 per cent.; lead, 12 per cent.; and phosphorus, 0·3 per cent. (4) Copper, 78 per cent.; tin, 10 per cent.; zinc, 4 per cent.; lead, 8 per cent.; and phosphorus, 0·6 per cent.

Swedish Iron Production.—At the last meeting of the Union of Swedish Ironmasters the report stated that for the first three quarters of 1912 the export statistics for all kinds of iron goods, except bar iron and billets, show an increase as compared with the corresponding figures for the preceding year. The decline in the two products referred to was during October turned into an increase. The export of pig iron continues at a high figure, and at the end of October the exports of the year exceeded those for the same period of 1911 by 33,700 tons. The different works have been fully employed; the production of pig iron during the first three quarters of 1912 was 30,900 tons greater than for the first nine months of 1911, and the production of iron and steel in blooms and ingots shows an increase of 23,600 tons. There were in operation during the third quarter of 1912, 103 blast-furnaces, against 84 for the same period of 1911.

CASE CARBONISING OF STEEL.

AN exhaustive paper on "Case Carbonising" was presented by Mr. M. T. Lothrop at a recent meeting of the American Society of Mechanical Engineers. The paper, which includes a large number of tables of results, contains much valuable information on the subject, based upon a series of exhaustive experiments. The investigations were undertaken with the object of pointing out the causes of and the results effected by irregularity, and the means and precautions which must be employed to produce uniformity, and the results obtained indicate that commercially case carbonising operations can be performed in such a manner that the final result will be absolutely uniform.

The first of the experiments was made in order to determine the effect of heat treatment in case carbonising. The materials used ran from 0·15 per cent. to 0·25 per cent. carbon, basic open hearth; 0·10 per cent. to 0·31 per cent., Halcomb electric furnace nickel steel; 0·20 per cent. and 0·49 per cent., Halcomb electric furnace chrome-vanadium steel, and 0·50 per cent., Halcomb electric furnace chrome-nickel steel. The general conclusions arrived at by the author from these tests are as follows:—

Strength and toughness decrease with increasing depth of case. This is important commercially, for with a certain steel and a certain heat treatment uniformity of strength and toughness is impossible if the depth of case varies.

The critical depth of case at which maximum brittleness and minimum strength occur depends upon the initial carbon content of the steel which is case carbonised. The higher the original carbon content, the smaller the ratio of depth of case to diameter of core at the point where this brittleness occurs. The commercial importance of this point is that the manufacturer using the steel for case carbonising should know its composition and should vary the depth of the carbonising effect as demanded by the composition of the metal being used.

Strength and toughness increase with double heat treatment. This result is to be expected, for the dual nature of case-carbonised steel requires two thermal treatments properly to refine the composite metal.

Strength and toughness increase when the temper is drawn at 380° Fah. This operation does not decrease the hardness but relieves in a greater or less degree the strains set up in hardening, and makes for uniformity, as well as more pronounced physical properties.

Annealing after case carbonising is a doubtful operation. The physical improvement with single heat treatment may be obtained by resorting to double heat treatment, for the results will be better and the time consumed in the operation much shorter. Annealing does not improve the double-heat treated pieces, and may even cause loss of strength and toughness, due to the decarbonisation which may take place. Annealing is not to be recommended.

The case-carbonised steel will, with either double or single heat treatment, become file hard at temperatures too low for the best development of the maximum strength and toughness. Although seemingly paradoxical, the dual nature of the steel after case carbonising will explain this established fact, when one recalls that the transformations of the exterior are first completed at low temperatures, and that those of the interior are last completed at higher temperatures.

All steels lose their file hardness when drawn at 425° Fah., save chrome vanadium, which loses it at 450° Fah.

The ideal heat treatment for a case-carbonised steel may be assumed to be: Case carbonise to the thinnest possible depth of case demanded by the conditions of service; reheat for the core; quench in a suitable fluid; reheat for the case; quench in a suitable fluid; draw the temper as far as the conditions of service will permit.

Case-carbonised steel parts, such as gears, &c., may be stronger, tougher, and harder than similar parts made from oil-hardened steels.

A microscopic experiment on the effect of heat treatment after case carbonising was made to determine, if possible, the constitutional difference between a case-carbonised bar of steel which had received a single heat treatment, and a piece of the same metal carbonised in the same manner which had received a double heat treatment, the first re-heating designed to be the best possible for the interior of the core and the second reheating designed to be the best possible for the case or carbonised zone. The results of this experiment indicate that the double heat treatment increases the strength and toughness of case-carbonised steel due to the smaller and finer martensitic structure developed.

Experiments were carried out to determine the lowest temperature at which case carbonising begins; the lowest temperature with each of the three different types of case-carbonising steels (straight carbon and alloy all of the same carbon content, viz., 0·20 per cent.) at which it might be most efficiently conducted in practice; and the best temperature for the case carbonising of steel. The steels used were (1) open-hearth carbon steel; (2) electric nickel steel; and (3) electric chrome vanadium steel. The following is a general summary of the results:—

The depth of case-carbonising effect in a given time increases with the temperature.

The carbon content in the case-carbonised zone in a given time increases with the temperature. This affords the commercial opportunity of varying the depth of case-carbonising effect as desired by changing the time, and of varying the carbon content of the case-carbonised zone by changing the case-carbonising temperature. It is poor practice to raise the temperature of the case-carbonising operation for the purpose of reducing the time which the operation consumes, for this will increase the maximum carbon content of the case-carbonised zone and may change the character of the physical properties of the finished product.

The minimum temperature at which uniform penetration of carbon can be obtained with case carbonising seems to be 1,500° Fah. With lower temperatures the carbon maximum is not uniform in its distribution and the penetration too slow.

The presence of excess cementite in the form of needles within the pearlite grains, so conspicuous in nickel and carbon steels, indicates a temperature during case carbonising which overheats the metal being so treated.

Nickel steel gives the greatest total penetration and greatest gradation zones.

Chrome vanadium gives the highest carbon maximum and finest-grained steel.

When case carbonising is conducted at 1,400° Fah. or lower, the carbon maximum does not exceed the eutectic. As the case-carbonising temperature increases, a zone of hypereutectic composition develops which increases in depth with the temperature. The depth of this zone becomes important when sufficient warpage takes place in the piece being hardened to demand grinding after the final heat treatment. It has been demonstrated often that a carbon content of more than 1 per cent. in the surface of a case-carbonised part is undesirable when there is the least shock to be reckoned with, because in such instances the excess of carbon exists in the form of films of carbide between the grains of the metal which are brittle and hard, weakening the steel and rendering it liable to fail by flaking off or spawling. Therefore it would be inadvisable to select a practice or a material which produces such a condition in the surface. On the other hand, if the carbon percentage is lower than 0·90 to 1·00 per cent., the case will not show its maximum hardness. Therefore, when pieces are to remain unground, practice should aim at a production of a 0·90 per cent. carbon surface, but when a portion of the steel is to be ground off, after the heat treatment, it is advisable to drive in an excess of carbon so as to leave this optimum percentage of 0·9 to 1·00 per cent. in the final surface.

All carbonised zones widen with increase of temperature. While wide gradation zones are desirable from the point of view of tenacity of the case to the core, other considerations enter into the commercial side of the problem. The first is the cost of maintaining the high heats. The factors of fuel cost and increased furnace up-keep cost at the upper temperatures are self-evident. The second is the difference in the

nature of the case. Inspection will show that at 1,500° Fah. the width of the eutectic zone is considerably greater than that of the hypereutectic zone, and the hypoeutectic zone of the decreasing carbon content is wider still, which means, of course, that the case carbonising is proceeding gradually and that the case and core are merging into each other by gentle degrees. At 1,600° Fah. the ratio of the high carbon exterior zone to the inner zones rises, and at 1,700° and 1,800° Fah. the increase is more marked still.

The meaning of all this is that as the temperature goes up carbon is forced by the heat, as it were, to rush into the surface of the steel faster than it can be assimilated by the adjacent grains, and so the outside layers at the high heats are gorged with carbon which has not time to diffuse gradually toward the centre of the case. This condition of affairs is highly undesirable, because the product then shows a sharp demarcation between case and core, the transition from one material to another being too abrupt; the properties necessarily vary accordingly, and in the finished piece have a tendency to set up high physical strains. This causes flaking off of the case from the core, a phenomenon familiar enough to those engaged in the trade. The remedy is to case carbonise at a moderate heat for a length of time sufficient to obtain a reasonable depth of case with gradual transition from case to core. This temperature appears in this experiment to be about 1,650° Fah. with open-hearth carbon steel, 1,600° Fah. with electric nickel steel, and 1,650° Fah. with electric chrome vanadium steel.

In deciding upon the best carbonising temperature, the effect of heat on the size of grain in the steel must also be considered. This, as is well known, is a very decided reaction, the grain coarsening rapidly with increasing temperatures. In this connection a careful investigation showed marked contrast between the behaviour of ordinary carbon steel and the two alloy steels; the former began to coarsen rapidly at 1,500° Fah.; nickel steel also showed the same effect at the same temperature but in a much less marked degree, and chrome vanadium steel retained its fine grain up to 1,700° Fah. and over, not reaching even at 1,800° Fah. the grain size of other steels. This is in line with the common belief that chromium and vanadium retain fineness of grain in steel.

The object of another experiment was to determine by chemical analysis the depth of carbonising effect and carbon content of several zones of case carbonising effect as effected by the composition of the steel being case carbonised. The information obtained from this experiment indicated that the higher the carbon content of the steel case carbonised, the higher will be the maximum carbon content of case when case carbonising is performed at a given temperature for a given time; the original carbon content does not affect the depth of case under the conditions of this experiment; the nickel and carbon steels behave similarly in regard to carbon maximum. Chrome vanadium steel takes a higher carbon maximum than nickel steel and carbon steel under the same case-carbonising conditions.

A further experiment was undertaken to determine the commercial efficiency of case-carbonising materials and the elements which affect their value commercially, 14 of these materials being selected for the purpose. The results obtained are summarised as follows:—

The volume per ton of case-carbonising materials varies. As these materials are used by volume, not by weight, this volume per ton must be considered in the economic purchase of this grade of material.

All the compounds show shrinkage of volume and in most instances a loss of potency with continued service. This point is of greatest commercial interest since, if steel of variable carbon content is produced in the case-hardening process, the manufacturer cannot hope for uniform results.

With the compounds on the market, any desired maximum carbon content in the case can be obtained with a given temperature simply by varying the compounds used.

When parts are produced which require grinding after treatment, a compound should be selected which gives a high maximum carbon content.

When parts are produced which require resistance to shock after heat treatment, a compound should be selected which gives a carbon maximum sufficient for the hardness desired and not in excess of this amount, or brittleness will result.

The ideal case-hardening compound, as indicated by the experiment, would possess the following characteristics: (1) large volume per ton; (2) small shrinkage per run; (3) high resistivity to change of shape or powdering; (4) cleanliness and freedom from dust; (5) uniform case-carbonising power at all runs; (6) capability of being used an innumerable number of times.

The information herein presented was obtained with the object of pointing out: (a) the quantitative effect of the commercial irregularities which creep into case-carbonised steel parts; (b) the precautions which must be observed if uniformity is desired; and (c) the physical characteristics in case-carbonising materials which must be considered if low cost for this operation is to be obtained.

The ideal case-carbonising compound perhaps has not yet been produced; however, compounds which are clean, mechanically strong, uniform in case-carbonising power, and capable of unlimited re-use are being commercially employed in case-carbonising operation.

MAKING HIGH-CONDUCTIVITY COPPER CASTINGS.

In view of the extensive demand for copper sand castings in the manufacture of electrical work at the present time, and the probable increase in this demand in the future, our contemporary, "The Brass World," calls attention to one requirement which is usually overlooked or not given the attention that it should. It is the fact that, in order to produce copper castings of high electrical conductivity, it is absolutely necessary that the copper used for making the castings be of a similar conductivity. Many brass founders believe that the material used for rendering the copper of high conductivity serves to purify it completely from all impurities, so that an impure copper can be used for the starting point and result in a pure copper of high conductivity. This belief is entirely wrong. In making copper castings in sand the matter is one of rendering them sound, and in order to do this some deoxidising material is necessary. It is the oxygen absorbed that causes the trouble, and to offset this, some metal or substance with a stronger affinity for it than copper is used as an addition to the latter metal to take it up and eliminate it, so to speak, from the copper itself. This deoxidising material, be it magnesium, silicon, manganese, or any other metal, has practically one mission, and that is to remove the oxygen. This statement may, perhaps, be modified by stating that with some other materials, like titanium, the nitrogen, if any be present, is likewise removed, and certain metals like manganese remove the sulphur. The two most frequently used substances for producing sound copper castings are silicon and magnesium, and these apparently only remove the oxygen. Impure copper, such as, for instance, commercial casting copper, contains as impurities arsenic, iron, antimony, sulphur, lead, and frequently bismuth, tellurium, and selenium. When melted, the copper oxidises to a greater or less extent, and when the silicon, magnesium, or other deoxidising material is added only the oxygen is removed. The other impurities remain and greatly lower the electrical conductivity of the copper casting. To make copper castings of high conductivity, therefore, it is imperative that the ingot copper used should likewise be of high conductivity. If this point is not heeded, the castings, though they may be sound and solid, will fall short in conductivity, frequently to a great extent.

Scarcity of Iron Ore in Japan.—At a meeting of the Japan Society held recently in London, Mr. A. Aoki, the Vice Consul of Japan, read a paper on industrial development in Japan. He stated that her mineral resources were great, but that iron ore was scarce. The total amount of iron and steel smelted from home-produced iron ore was only 350,000 tons, of the value of £1,800,000. The greater proportion of iron and steel required for her industries had therefore to be imported.

THE REACTIONS OF THE PUDDLING PROCESS.

At a meeting of the West of Scotland Iron and Steel Institute, held on Saturday last at Coatbridge, Prof. T. Turner, of the University of Birmingham, read a paper on "The Reactions of the Puddling Process." He said it was now more than half a century since the introduction of the Bessemer process startled the civilised world, and threatened the entire extinction of the trade in malleable or wrought iron. For nearly 20 years the older process suffered comparatively little from the attack of its young and vigorous rival, but the gradual introduction of mild steel for rails, plates, wire, and guns gave such a shock to the iron trade that when the bad times of the later seventies came the whole iron industry was again threatened with extinction. To-day they saw a most remarkable change in the relative position of the two processes. Bessemer steel was now threaened by its newer open-hearth rivals, its annual output diminishing, and its continuation was held by some competent observers to be problematical.

The wrought-iron trade, on the other hand, after having shrunk to relatively insignificant proportions, now showed signs of permanency, and even of expansion, which was certainly unexpected only a few years ago. At the end of 1912 there were in the South Staffordshire and North Worcestershire district 32 firms engaged in the production of puddled iron, operating 661 furnaces, and employing about 10,000 hands. During the last year or two the demand for really capable puddlers had exceeded the supply, and there was a call for younger men to train for the work. The reasons for the adoption of steel were obvious and clear, and for rails, wheels, and many similar purposes, no enthusiast would be so bold as to dream that wrought iron could ever replace steel. On the other hand, it must be acknowledged that wrought iron had certain properties which were largely responsible for the fact that this variety of material was to-day in increasing demand. Among these properties were the readiness with which it could be welded or otherwise smithed, its trustworthiness under certain kinds of shock, and its power of resisting atmospheric action.

Though the continued demand for wrought iron was due to the qualities of the material itself, there were several other causes that had contributed to the result. Certain kinds of pig iron which were suited admirably for puddling were not so well adapted for steel making by any of the larger processes. So long as the argillaceous and the brown ores of this country were available, so long should we have pig iron suitable for use in the puddling furnace. As regarded the possibilities of increasing the output, lowering the cost and improving the quality of the product, it might at once be confessed that the hope of any revolutionary change was remote. It was probably by careful attention to details rather than by changes in principle that the best results would be obtained. There were in all businesses certain commercial considerations. The attention of the metallurgist was concentrated rather upon what went on inside the works, and the more commercial aspects were dealt with by the commercial staff, whose training was often less extensive, but whose remuneration not infrequently was on a higher scale.

Among the questions that confronted the metallurgist were the quality of the pig iron employed, the quality and consumption of fuel, the character of the fettling, the most suitable size and shape of furnace, the reactions which took place while the impurities of the iron were being removed, the losses during conversion, and the quantity and quality of the iron and the top cinder. After dealing with the various processes and the reactions, Prof. Turner said there was a trustworthiness and quality in puddled iron that had been well made by the ordinary process, such as could not be exactly reproduced either in the best steel or with regularity in any large mechanically-worked furnace. The future of wrought iron was, he believed, more dependent upon quality and uniformity than upon rapidity or output or reduction in price. Economy of fuel was to be looked for rather in the direction of the use of cheaper fuel, the complete combustion of its carbon, and the utilisation of the waste heat for steam-raising or other purposes.

SPECIFICATIONS FOR MACHINERY CASTINGS.

BY JOHN JERMAIN PORTER.

In most lines of machinery, cast iron is by far the most important material of construction. In such important classes as machine tools and engines it forms not less than 90 per cent. by weight of the finished machine, and it is probable that more than 1,500,000 tons of cast iron will go this year into the construction of machinery.

Notwithstanding this extensive use, machinery castings are ordinarily bought and made with only the haziest of concepts as to the properties necessary in the material, and with only the loosest of specifications to control the quality. It is not unusual for an order to state only the number of castings desired, and it is rare indeed that there is any effort to specify or determine quality beyond the simple statement that the castings must be true to pattern and free from blowholes and similar defects.

Contrast this condition with the great attention paid to steel as a material, the most careful study being given to the properties desired and their attainment. In almost every case its composition and properties have been tested at some stage of manufacture and it is usually bought on fairly complete and stringent specifications.

We do not have to go far to seek the reasons for this difference. Steel is a homogeneous material and the properties of the test piece represent with a fair degree of accuracy the properties of the structure made from the same material. Hence, the engineer can with safety design his parts according to the data secured from the test piece. Moreover, the relation of composition and method of manufacture of steel to its properties is well understood.

On the other hand, cast iron is essentially a non-homogeneous material and has the reputation of being extremely variable and untrustworthy. For this reason engineers find it necessary to allow so large a factor of safety that ordinary differences in strength are not worth considering. It is to be feared, however, that to many engineers and users cast iron is simply cast iron, and there is no appreciation of the great differences possible in the material.

Now, while it is true that cast iron is not like steel and cannot be expected to remain as uniform in its properties, nevertheless its bad reputation in this respect is largely a heritage of the past and need not apply to the product of the modern foundry.

The first point to be considered is what we expect to accomplish by the use of specifications or standards of quality. Since their use presupposes definite knowledge of the properties desired in the material in many cases their greatest value is in focussing attention on this point and thus indirectly bettering the quality of the product. Assuming the properties to be desired are known, buying on specification furnishes the only sure means of getting the results desired.

When we mention specifications the average foundryman or user of cast iron thinks only of strength, and it is well known that in a large number of machinery castings strength is of relatively small importance, since the parts must be designed for weight and rigidity and therefore contain an excess of metal over that required by mere considerations of strength. However, there are many other properties to be considered, such as hardness, wearing power, porosity, colour, ability to take a polish, elasticity, &c., and some of these are frequently of much more importance than strength. The ability to take a polish, for example, is of very great importance to machine tool builders, who as a rule pay much attention to the appearance of their product and use polished surfaces freely. One who has never investigated this matter would be surprised at the great differences in the appearance of polished castings of otherwise similar properties. Another example is the case of automobile and gas engine cylinders, which must first of all be free from porosity and, secondly, should have the greatest resistance to wear consistent with sufficient softness to permit machining. Enormous differences in both properties are possible in castings of equal hardness.

Although the improvement of product is thus the chief advantage to be anticipated, it may in some cases be possible to effect some reduction in the cost of manufacture by means of specifications, owing to the greater uniformity of the metal and the elimination of hard castings. As a usual thing buying on specifications means a broader field for the purchase of materials and a better price, but in this case, owing to the

fact that most foundries are not prepared to furnish castings of guaranteed or known properties this advantage cannot be expected. On the contrary, a narrower field and a higher price are very apt to be the result.

I do not propose to do anything so bold as to attempt to draw up model specifications of general applicability, but it may not be amiss if I discuss the general principles to be applied to the case of cast iron. The steps involved are: First, to decide on the properties desired; second, to determine how they shall be specified whether directly, and if so, in what terms, or whether indirectly, by specifying composition, method of manufacture, and other controlling factors; third, to provide a system of inspection and tests or other means of determining whether the specifications are being fulfilled.

The properties desired depend on the casting and its use. In most machinery parts hardness is probably the most important property, with strength and ability to take a polish following closely. In castings such as lathe and planer beds, the resistance to wear (in the vees) is of considerable importance. The case of engine cylinders has already been mentioned. In some cases stiffness is of some importance, and there are other properties which occasionally need consideration. In general, however, we have two classes of castings: First, general machinery castings in which the important properties are softness, the ability to take a good polish, and strength; second, cylinders and to a less extent lathe beds and similar castings in which close grain and resistance to wear are of prime importance, although they must be accompanied by good strength and a reasonable degree of softness.

To decide on these properties as desirable is an easy matter; to find means of specifying them is often more difficult. Such properties as strength and hardness are easily specified directly. Strength is measured by a tensile or transverse test bar, preferably cast, attached to certain castings. Hardness may be measured on the casting itself by means of the Shore scleroscope or by the drill test, on a separate test piece. There is now in existence no recognised test for resistance to wear. It should not be impossible to devise one; but as the factors influencing this property are now fairly well understood, it is perhaps more satisfactory to get the desired results by the indirect method of specifying composition and method of manufacture. The same is true as to the property of closeness of grain, ability to take a polish, and freedom from porosity.

As a general proposition it is better not to hamper the manufacturer by required composition and method of manufacture, but to hold him responsible for results only. However, there are some properties, such as the last mentioned above, which are so intangible as to render it very difficult if not impossible directly to measure them satisfactorily. In the case of steel also it has been found that tests of the material alone cannot satisfactorily cover the ground, there being service differences which are not discovered by inspection or laboratory tests, but which depend upon and hence can be controlled by composition and method of manufacture.

Finally, there is the matter of a system of inspection, tests and records which will show whether specifications are being lived up to. Such a system to be successful must be simple and not involve burdensome detail or expensive features. In the average plant skilled testing engineers are not available, hence the tests must be simple enough to be made by men of average intelligence and without special training, and also without the use of excessively expensive apparatus.

In my experience I have obtained very satisfactory results by the use of only one test piece, or rather one kind of a test piece—a bar 13in. long by 1in. square in cross section, several of which are poured along with the casting or preferably cast attached as coupons to certain representative or important castings. If this latter plan is followed there is no possible chance for fraud or for the bars from different heats and mixtures becoming mixed up.

It is well to state in this connection that the size of the test bar should bear some relation to the thickness of the castings, owing to the well-known fact that the structure and properties of cast iron are a function of rate of cooling, as well as composition and method of melting. It is not, however, necessary to have the section of bar to exactly correspond with the thickness of the casting. Indeed, this is usually an impossibility, since castings are not always uniform in section. The 1in. square bar is fairly representative of the great bulk of ordinary machinery castings. For very light work a ½in. square bar would be preferable, while for heavy rolling mill and engine castings a 2in. square bar would be better.

These test bars when broken on a transverse testing machine serve to determine strength, and the broken pieces can then be subjected to a drill test for hardness. The 1in. square bar which I have advocated is slightly less accurate than the American Foundrymen's Association standard test bar, which is a 1¼in. diam. round bar cast vertically. It is this provision of vertical casting which makes it not feasible to use this test bar for routine work. The drill test can be carried out in a number of ways, but one method which I have found advantageous, because of its ideal simplicity, is to attach a lever and weight to the hand feed of an ordinary drill press in such a way as to produce a constant pressure on the drill point. A revolution counter is also used to record the revolutions of the drill, and the number of revolutions required to drill entirely through a piece of 1in. test bar is taken as the numerical measure of hardness. Of course, it is necessary to take an average of several observations in order to get a reliable figure.

The Shore scleroscope may also be used to test hardness. It possesses the advantages that the test is quickly carried out, that it is portable and may be carried to the work, and that it can be used directly on the casting, thus eliminating the necessity of a test piece. It possesses the serious disadvantage that it measures surface hardness only and at a very minute area of the surface. This is not objectionable in the case of a homogeneous material like steel, but in the case of a non-homogeneous material like cast iron the indications of this instrument are very uncertain. The instrument is also less sensitive on cast iron than is desirable.

In my opinion these are the only tests ordinarily necessary and desirable, but in addition I would specify limits of composition, the presence of special elements in some cases, and the use of steel scrap (semi steel) for some work.

Although it is evident that cast iron does not lend itself as readily as steel to specifications, still from a technical standpoint there are important advantages in purchasing on this basis. Commercial feasibility, however, is another thing, and as I see it there are three objections to any attempt to change the existing method of purchase.

In the first place, is the difficulty in formulating satisfactory specifications. This is a matter which calls not only for an intimate knowledge of foundry practice and of the chemistry and properties of cast iron, but also an equally intimate knowledge of commercial conditions, together with good business judgment. It is not every builder of machine tools or other machinery that possesses this knowledge within its organisation, and if obtained outside the cost is a factor to be reckoned.

Second, is the difficulty in getting foundries to bid on specifications. Foundry progress has been slow, because the business could be carried on in a small way, and until recently there has been no great economy in large plants. Indeed, this latter condition still holds true for foundries doing jobbing work. Small plants, on account of the necessity of keeping down overhead charges, cannot command a high grade of technical skill. Within recent years great progress has been made both in mechanical equipment of the foundry and in the technical knowledge of cast iron. This progress has been so widely exploited through the technical press that we are likely to think of the industry as completely emancipated from the thraldom of ignorance and old-fashioned methods. This, however, is not the case; the up-to-date foundries are still in the minority, and small plants operated along old-fashioned lines are still in the majority, especially among the jobbing foundries.

Because of these conditions, there is apt to be more or less trouble in getting foundries to bid on specifications, and a restricted number of bidders makes for higher prices. A foundry to handle such work successfully would have to em-

ploy a chemist and have facilities for testing. It should have these anyway, but few do have, and those that do often feel entitled to a higher price for putting on these "frills." This general condition is probably the greatest obstacle to any attempt to buy castings on specifications. It is not an unsurmountable obstacle, however, for the writer knows of a number of cases where grey iron castings are successfully bought on specifications, including both composition and strength. It is fair to say that in some of these cases, at least, higher than market prices are the result.

The third difficulty is the trouble of operating specifications and the cost of making the necessary tests and inspections. To some shops these difficulties are negligible and to others so great as to practically forbid the use of specifications. It depends largely on the organisation available. While the amount of testing required is small, the cost will still be considerable if it is done in an outside laboratory. If done within the plant the cost will be small; but to be successful it must be in the hands of the right kind of a man who has a reasonable amount of interest in the work. Moreover, the results of the tests must be carefully followed up or they are of no use.

The following conclusions summarise the preceding discussion:—

1. It is technically possible to secure cast iron of special properties and castings which are much better adapted to their use than is generally the case.

2. In attempting to get an improved quality of castings by means of specifications it is essential to have competent advice as to what it is reasonable to expect in cast iron and how it is possible to obtain the desired properties.

3. An attempt to buy on specification at the present time is likely to result in an increase in the cost of the castings.

4. No exaggerated idea of the benefits to be derived should be entertained. These benefits are mainly indirect and are such as result from the more exact and definite knowledge of the material used. They will show chiefly in an improved quality of the product.

5. Specifications are only a tool, and like other tools, are useless unless there is a directing brain and guiding hand back of them.

6. The management of any shop which aims to operate according to the principles of scientific management should have definite standards of quality for the castings used, and such knowledge of the castings as is only obtained by a regular system of testing. There are many cases where actual purchase on specification is not warranted by commercial conditions, but where considerable improvement in quality can nevertheless be obtained if the properties desired are definitely known and sought and there is definite knowledge of the quality.—"The Iron Age."

INDUSTRIAL AND TRADE NOTES.

British Iron and Steel Production.—Particulars have been published by Mr. C. J. Fairfax Scott, secretary of the British Iron Trade Association, of the production of pig iron, Bessemer steel ingots, open-hearth steel ingots, and puddled bars in Great Britain during the first half of 1912. According to these the production of pig iron during the period in question was 3,606,147 tons; Bessemer steel ingots, 674,251 tons; open hearth steel ingots, 2,327,731 tons; and puddled bars, 167,260 tons. All these figures show a reduction when compared with those for the first half of 1911.

Record Trade Returns for 1912.—The trade boom is reflected in the Board of Trade returns for last month, recently issued, and show that the total value of the imports during December amounted to £74,068,698, as compared with £64,937,887, an increase of £9,130,811. The exports for last month reached a total value of £41,159,038, or an increase over the corresponding month of last year of £2,887,159. For the year ended December 31st the imports amounted to £744,896,511, an increase as compared with 1911 of £64,738,987. The value of the exports during 1912 was £487,434,002, an increase of £33,311,701 over the figures of the previous year.

Iron Ore Output in 1911.—The Home Office returns just issued show that the output of iron ore in the United Kingdom during 1911 was 15,519,424 tons, valued at £4,035,893, as compared with 15,226,015 tons, valued at £4,022,269 in 1910. These figures show increases of 293,409 tons and £13,624 respectively. Of the total in 1911, 9,710,693 tons were obtained from mines and 5,808,731 tons from quarries, these amounts showing a decrease of 120,408 tons and an increase of 413,817 tons respectively on the previous year. Including imports, the total quantity of iron ore available for furnaces in the United Kingdom in 1911, exclusive of mill and forge cinders, was 22,496,727 tons, a reduction of 349,953 tons as compared with 1910. The average value of the whole output under the Coal Mines Act in the United Kingdom in 1911 is returned at 5s. per ton, being the same figure as in 1910.

The Globe Ironworks, Bolton.—An important meeting was recently held of those interested in the reorganisation of Messrs. Musgrave and Sons, Ltd., Globe Ironworks, Bolton, which firm has been in liquidation for some months. Mr. William [illegible] presided and holders of debentures to the amount of £68,000 were represented. Mr. J. P. Garnett, acting on behalf of a number of persons who propose to form a new company, asked for an option to purchase the business of the present company at a certain price. The meeting by a large majority authorised the trustees to grant the option. It is understood that under the arrangement proposed the owner of each £100 worth of debenture stock will get £60 in debenture stock of the new company and receive £10, plus interest, and, if the funds will allow, a premium of 5 per cent. in cash. The works when fully occupied employ some 3,000 men.

A Blow to Collective Bargaining.—Mr. Thomas Burt, M.P., in his monthly circular to the Northumberland Miners' Association writing of the recent railway strike, says: "The strike afforded another illustration of what has been but too common of late, that is of a section of men hastily stopping work without notice, in violation, too, of the rules of their trade union, and against the advice of their duly appointed leaders. Beyond doubt these sudden outbursts weaken, discredit, and dishonour the trade union movement, and strike a damaging blow at the very principle and essence of collective bargaining, which has proved a great boon to the workers, and which was won after many years of arduous struggle and conflict. Practically the railway workers acknowledge that they were in the wrong, as to method of procedure, by having agreed to accept a substantial fine in the shape of a deduction of a week's wage from those concerned."

Scottish Pig Iron.—The Scottish Ironmasters' Association have issued the official return of the iron trade for the past year, showing that the production of pig iron was 1,198,767 tons, being 203,032 tons less than in the preceding year. The consumption in foundries was 211,261 tons, an increase of 13,021 tons, and the quantity used in malleable iron and steel works was 899,787 tons, a decrease of 1,974 tons. The exports were 291,100 tons, a decrease of 21,041 tons. The total consumption and exports, taken together, show a decrease of 9,994 tons. The pig iron remaining in stock amounts to 118,651 tons, and the stocks have decreased by 203,336 tons. The reduction of stocks, though large, is less than was anticipated, and the returns as a whole suffer from the effects of the miners' strike, during which furnaces were out of blast. The number of furnaces in blast was 90, against 85 a year previously.

Shipyard Schemes in Canada.—According to a correspondent of the "Sheffield Daily Telegraph," Messrs. Cammell, Laird, & Co. have decided upon the establishment of a shipyard at St. Johns, New Brunswick, which is to be completely equipped for the construction of the largest war and merchant vessels. This departure has been under consideration for some time. Moreover, the firm of Sir W. G. Armstrong, Whitworth, & Co., Elswick, is mentioned as likely to be responsible for a similar enterprise in another part of the Dominion, and Halifax, Nova Scotia, is said to be strongly favoured in this connection. At Montreal, Messrs. Vickers, Ltd., have for some time been laying down plant for the building of Dreadnoughts, cruisers, and destroyers, whilst at Sydney, Cape Breton, a syndicate, in which Messrs. John Brown & Co. and the Fairfield Company, Govan, are jointly interested, is also providing facilities of the kind. This syndicate is to undertake the manufacture of armour plate, guns, and gun munitions.

Highland Railway for Sale.—The Invergarry and Fort Augustus Railway is for sale. The line, which is 24 miles in length and connects Spean Bridge and Fort Augustus in the Scottish Highlands, cost £360,000. It was opened in 1903 and closed to traffic in 1911. At the time of its inception promises of traffic support came from proprietors, farmers, and others, but these promises were not fulfilled. The Caledonian Canal steamers when the

line was opened promptly lowered their rates for goods and passengers, and the business merchant sent his goods by steam boat, although the railway was the speediest route. Consequently the line was worked at a yearly loss. The Invergary Company announced in 1910 the intention to stop traffic. This aroused much excitement, for the line was good for tourists, holiday visitors, and other passenger movement, as well as rapid goods transit. A guarantee for a year was given by proprietors, merchants, and farmers that the bulk of their goods traffic would in future go over the line. The year's operations, however, did not prove successful, and the railway ceased active duties in 1911. Since then it has been derelict. The railway will be sold off early this year in lots to suit purchasers.

Record Shipbuilding.—The returns compiled by Lloyd's Register of Shipping, which only take into account vessels the construction of which has actually begun, show that, excluding warships, there were 542 vessels of 1,970,065 tons gross under construction in the United Kingdom at the close of the quarter ended December 31st, 1912. The figures are the highest on record, easily beating those for the September quarter, which held the record to that date. Of the ships being built 506 of 1,960,330 gross tonnage were steamers, and 36 of 9,735 tons were sailing vessels. The increased activity is shared by every shipbuilding district of importance in the country, Glasgow heading the list with 114 vessels of 467,344 tons. The marked tendency of the mercantile steamship still further to increase in size is indicated by the following figures: Two of the vessels now building are over 40,000 tons, one between 30,000 and 40,000, one between 20,000 and 30,000, ten between 15,000 and 20,000, nine between 12,000 and 15,000, 16 between 10,000 and 12,000, and 15 between 8,000 and 10,000 tons. During the quarter 228 vessels were commenced, and 213 were launched. Three hundred and sixty-nine of the 542 ships are owned in the United Kingdom and 36 in the colonies, the next largest figures being Holland 15, and Brazil, France, and Norway 14 each. Warships under construction in the Royal dockyards of the United Kingdom numbered 15 of 154,840 tons displacement. Those at private yards numbered 69 of 342,035 tons, of which 57 of 224,385 tons were British and the remainder foreign.

Coal Mines Act: Draft of New Regulations.—The Home Office have issued a draft of general regulations for mines under the Coal Mines Act, 1911, which the Home Secretary proposes to make. The regulations are divided into seven parts. Part 1 contains the regulations under Section 86, providing generally for the prevention of accidents and the safety, health, convenience, and proper discipline of the persons employed, and will take the place of the general codes of special rules at present in force in the different districts. Part 2 consists mainly of regulations on certain specific matters in respect of which the Act requires or authorises regulations to be made. Part 3 embodies the existing special rules on the subject of the installation and use of electricity, with such drafting alterations only as are required by their transformation into general regulations under the Act of 1911. Part 4 contains provision as to rescue and ambulance. The rescue provisions embody the rescue Order already in force without alteration, except that the temporary provision in Clause 5 (a) of the Order has been omitted, and a minor alteration has been made in Clause 3 (b). Part 5 embodies the existing special rules as to surface lines and sidings with the alterations required by the transformation of the rules into regulations under the new Act. Part 6 contains regulations for sinking pits based on the special rules now in force in different districts. Part 7 revokes all existing special rules. Copies of the regulations may be had by persons affected on application to the Home Office; and any objection must be sent to the Secretary of State before March 1st.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Treatment of steel or iron surfaces for hardening. Simpson. 20917.
Extensometers. Pye. 28423.
Gas and air compressor. Lare. 28588.
Brake chains. Spary. 28597.
Bearings for mounting wheels on axles. Bergishe Patentachsen fabrik Ges. 28603.
Lubricating systems and apparatus for internal combustion engines. Adams & Adams. 28614.
Steam-superheaters for locomotive boilers. Robinson. 28708.
Flying machine. Keller. 28815.
Mechanically-operated poker for retort furnaces. Gill. 29127.
Apparatus for measuring steam consumption. Von Lossau. 29189.
Apparatus for controlling the speed of steam-engine. Robertson, Murray, & Smith. 29269.

1912.

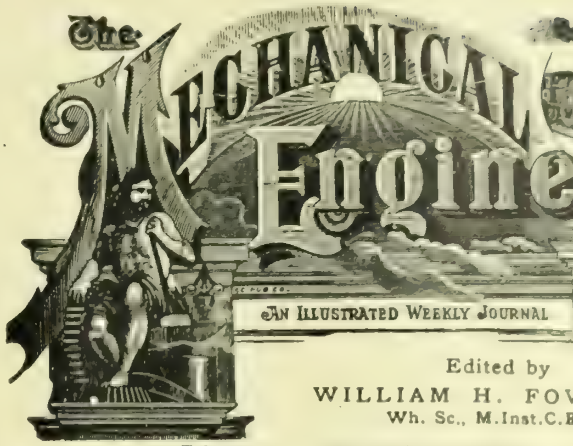
Carburetter for use with gas-making machines. Frain, Simpson, and Eaton. 17.
Rotary piston engines. Pratt. 69.
Apparatus for charging retorts. Williams & McPhee. 415.
Multiple-delivery lubricator. Bureau. 451.
Chucks for boring and drilling machines. Swinburne & Crawford. 1227.
Automatic mechanical devices for controlling other mechanisms. Herbert & Vernon. 1329.
Nut locks. Schmidt. 1353.
Two stroke-cycle internal-combustion engines. Beardmore and Stokes. 2495.
Method of hydraulically transmitting power and a hydraulic power plant operated in accordance therewith. Spillmann. 3429.
Process for the treatment of sulphide ores containing lead and zinc. Richards. 3951.
Automobile road vehicles. Blum. 4497.
Apparatus for exhausting or compressing air. G. & J. Weir, Ltd., and Petermoller. 4853.
Internal-combustion engines. Cherix. 4902.
Rock drilling machines. Kubat. 6202.
Starting systems for internal-combustion engines. Sunbeam Motor Car Company, and Coatalen. 6490.
Lubricator. Thomas. 7918.
Pneumatically driven tools. Jenkins. 8198.
Valve mechanism for internal combustion engines. Rosner. 9326.
Centrifugal compressors. British Thomson-Houston Company. 10263.
Propulsion of vessels. Mills. 10734.
Means or method of obtaining energy. Hyde. 11213.
Pneumatic brakes. Chapsal & Saillot. 12780.
Carburetters for internal-combustion engines. Snow. 13961.
Pulley blocks. Anderson. 14131.
Steam superheaters for locomotive boilers. Robinson. 15039.
Central buffer with automatic coupling device. Manzano. 15112.
Internal-combustion engines. Kind. 15133.
Expansion bolts. Mower. 15829.
Process for briquetting flue dust. Hubner. 16092.
Piston rings. McQuay & Norris. 17052.
Tube-cleaning apparatus. Brindley, and Boiler Scalers, Ltd. 17229.
Bolts and nuts. Kokkelkoren & Linet. 17400.
Nut locks. Wich. 17591.
Process for the manufacture of plastic metallic packings. Fried. Krupp Akt.-Ges. 17648.
Dust-proof grinding and polishing chambers. Linsenmann and Wagener. 21462.
Stator blades for steam turbines. Fried. Krupp Akt. Ges. Germaniawerft. 24308.

ELECTRICAL, 1911.

Wall plugs for electrical purposes. Gibson. 28837.
Controllers for electric motors. Turner. 29138.
Magnetic separators. Fried. Krupp Akt. Grusonwerk. 29221.

1912.

Systems of electric distribution. British Thomson Houston Company, and Young. 627.
Electrical means for controlling electrically driven apparatus. Holmes, and Automatic Advertising Company. 1569.
Electric switches. Railing & Strachan. 4577.
Trolley collectors for electrically-driven tramcars. Estler. 5469
Magnetos used with internal-combustion engines Bentall and Bingham. 5629.
Device for attaching overhead line wires to insulators. Paton. 5636.
Automatic spark timing mechanism for internal combustion engines. Townson. 6077.
Switches combined with plug terminals for electric circuits. Watson. 6673.
Electrical indicating apparatus. Soc. Courtand G. Garnier, Gil et Cie. 7780.
Electro magnetic brakes. Albert Thode & Co 18440.
Apparatus for automatically operating gas or electric lamps Oliver. 23993.



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Edited by
WILLIAM H. FOWLER
Wh. Sc., M.Inst.C.E.

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The Accuracy of Heat Engine Indicators.

ALTHOUGH the principle of the indicator diagram as a record of the relation between the pressure and the movement of the piston in the cylinder is essentially the same as it was when the instrument was first invented by Watt, the operating mechanism has, since his day, undergone considerable modification, first by McNaught, and subsequently by Richards, Thompson, Tabor, Crosby, and others. The improvements of these various inventors have all more or less consisted in refinements with a view to diminish obvious defects in earlier forms arising from friction and inertia of the many parts, and which became more pronounced with the advance of higher pressures and speeds, earlier cut-offs, and the struggle for greater engine economy. The efforts in this latter direction have, as we know, led to much more searching enquiries into all thermodynamic questions, and the development of the gas engine particularly served to accentuate some of the inherent defects in the ordinary indicator mechanism. Out of this has sprung an entirely new design by Prof. Bertram Hopkinson, in which pencil friction and other incidental troubles are largely eliminated. This formed the subject of an exhaustive paper to the Institution of Mechanical Engineers in 1907*. The question of indicator defects has formed the subject of enquiry in the technical papers on several occasions. Prof. Osborne Reynolds and Dr. Brightmore were the first to take it in hand seriously, and the results of their investigations were embodied in a paper before the Institution of Civil Engineers in 1885.† These experiments were of great value as showing the various possibilities of error and the corrections to be made for them. Some of their conclusions have, however, since been questioned, while others were incomplete. Since that date heat engine research has depended more and more on the accuracy of indicator diagrams, as has

* See Proc. Part IV., 1907, page 863, also "The Mechanical Engineer," October 26th, 1907, page 577, Vol. XX.

† See Proc. 1885, Vol. LXXXIII., page .

been shown in Profs. Callender and Nicolson's classic experiments on the temperatures in the steam engine; Prof. Burstall, in his gas engine researches; and Mr. Dugald Clerk and Prof. Bertram Hopkinson in their investigations respecting the specific heat of gases. In ordinary steam engine work an almost absolute reliance is placed upon it for deductions respecting the dryness fractions of the expanding steam, and the entropy diagrams drawn from them. In view, therefore, of the important part the instrument plays, apart from its practical applications for measurements of power, an accurate knowledge of the errors of the instrument, and of methods of eliminating them, is very desirable. Hopkinson's optical indicator for purposes of research work, especially in gas engine practice, where, owing to abnormally high initial pressures and early cut-offs, errors are liable to seriously affect calculated results, certainly affords a greater approximation to accuracy than is afforded by many of the ordinary types of indicator, though in a paper* by Prof. Burstall on a comparison between the Hopkinson and the Crosby types of instrument, he arrived at the conclusion that there was little to choose between the two on the score of accuracy, and that both gave results very close to the truth. The working of indicators, it will thus be seen, has been the subject of considerable investigation, but the question has not been by any means exhausted, and a further important contribution was made in a paper by Mr. James G. Stewart to the Institution of Mechanical Engineers on Friday last, and the publication of which we commence in another part of this issue. Mr. Stewart records a painstaking research conducted with a view to determine as near as possible the two principal sources of error in the ordinary indicator, viz.: (1) The discordance in pressure at any point in the stroke between that recorded by the diagram and that existing in the cylinder—due either to friction or to inertia of the moving parts, or both in conjunction; and (2) errors arising from the position of the drum not corresponding to the position of the piston due to stretch of the string or to straining in other parts of the indicator gear. As we are reproducing the paper it is hardly necessary for us to discuss the points in detail, though a note may be made of his most salient conclusions and observations on the design and working of indicators generally for those who use the instrument mainly as a means of approximate power measurement and general engine working. Those who use the instrument as a means of accurate research will doubtless study the paper in detail.

Briefly, Mr. Stewart's experiments show that the errors in indicator diagrams are much greater than have usually been assumed, and that as a result of friction and inertia there is a lag, often very great, of the pencil behind its true position, and further that this error is not a constant, but generally increases with the stiffness of the spring and pressure, and hence is liable to introduce the greatest errors where their effect on the diagram is most serious. Amongst hints given by the author for improvements in the mechanism of such instruments, considerable importance is attached to the desirability that the push on the indicator piston must be accurately in the axis of the cylinder for all pressures. For this reason the use of a single spring is objectionable, since, if it is compressed, the axis of its end bosses can only be kept coincident with the axis of the cylinder by the introduction of constraining couples, which introduce large errors in the diagrams. The best way to eliminate this is to use a double coil spring, though this device is not perfect, since it is almost impossible to secure two springs that are absolutely uniform. In the author's opinion no indicator recognises sufficiently the necessity of simple axial forces throughout the whole range of motion of the indicator piston, and since workmanship is never absolutely accurate, the design should be such that small inaccuracies will not introduce large constraining forces, and further, should avoid unnecessary restraint upon spring or piston. Mechanical linkwork must always be more or less unsatisfactory, even when constructed and used with the greatest care, as looseness of the joints cannot be avoided, and for this reason the optical indicator shows to advantage, as it also does in cases where rapidly changing pressures have to be recorded. Its accuracy also makes it pre-eminently fitted for high speeds or for accurate work, where the indicator drum, owing to its errors, would be unsatisfactory. The optical indicator, however, is hardly one that can be put into the hands of the ordinary engine attendant, and for general work one or other of the several types of instruments now in use must be relied upon. Apart from errors in the indicating mechanism itself, others are liable to creep into diagrams through neglect of precautions that are obvious to most careful experimenters, though they are often overlooked, and for that reason it may be worth while to mention some of them. The presence of water in the indicator or its connections, for instance, may not only alter the shape of the diagram, but may introduce a large error in the measurement of mean pressure, especially in high speed engines. Making the connection between the indicator and the cylinder of too small a bore may, on account of its relatively large radiating surface, give rise to condensation, and in particular cases set up oscillations in the steam or gas connecting pipes. This defect, more frequently met in gas engines than in steam engines, since a long pipe in the former case cannot always be avoided, and the necessity for a large bore is not so evident as it is in the latter. Inaccuracy obviously occurs if the spring and its scale do not agree, and it is not generally known that a difference of between 2 and 3 per cent. exists between springs calibrated at ordinary temperatures and at 212° Fah., and though in steam engine work little error is involved if the springs are calibrated at 212°, this is not true of gas engine work, and all that can be done to correct it is to form a rough estimate of the probable working temperature of the spring when used in the particular way adopted. Slackness in the joints of the pencil gear or screw of the piston rod is often a serious trouble, and careful handling and periodic adjustment are necessary if this is to be avoided. The sampling of diagrams is another matter to which sufficient attention is sometimes not paid, and without proper care in this respect large errors in the indicated power may be introduced, especially where the diagram area is subject to large variation. In steam engines, with good governing, sampling is not difficult, but in gas engine work where the variation is often large, especially with producer gas, the case is different. Errors may of course be easily introduced by careless measurement of diagram areas, though these can be practically eliminated by the careful use of the planimeter.

* See Proc. Inst.M.E., Part III., 1909, page 785; also "The Mechanical Engineer," August 6th, 1909, page 159, Vol. XXIV.

Institution of Mining and Metallurgy.—The Council of this Institution announce that the first awards of the Brough Memorial Medal have been made to Mr. Laurence C. Hill and Mr. H. Eyden for excellence in mine surveying whilst taking their associateship course at the Royal School of Mines.

WEIR'S APPARATUS FOR EXHAUSTING OR COMPRESSING AIR.

THE accompanying illustrations show a design of apparatus, the invention of Messrs. G. & J. Weir, Ltd., Cathcart, Glasgow, and Mr. J. Petermöller, for exhausting or compressing air or other elastic fluid by means of an auxiliary liquid medium, such as water, which is projected from a rotating turbine wheel into discharge nozzles and, by impact and entraining action, delivers the air into and through the nozzles. The apparatus is adjustable according to the volume of air or other elastic fluid which it is required to discharge in a given time, so that the power required to drive the apparatus, and the quantity of water employed, are not necessarily constants, but can be reduced with reduction in the volume of air which is dealt with. Fig. 1 is a section on the line 1—1 of Figs. 2 and 3; Fig. 2 is a section on the line 2—2 of Figs. 1 and 3; and Fig. 3 is a section on the line 3—3 of Fig. 1.

In Figs. 1, 2, and 3, R is the turbine rotor mounted on the shaft S, which is adapted to be rotated by any suitable

FIG. 1.

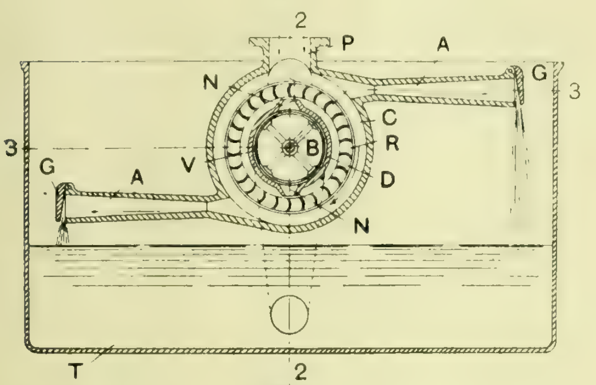
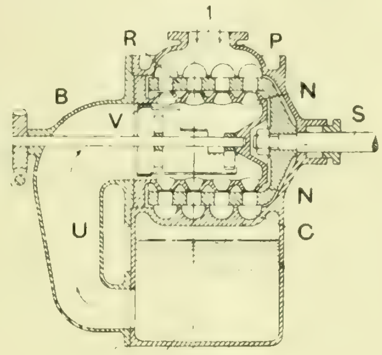


FIG. 2.



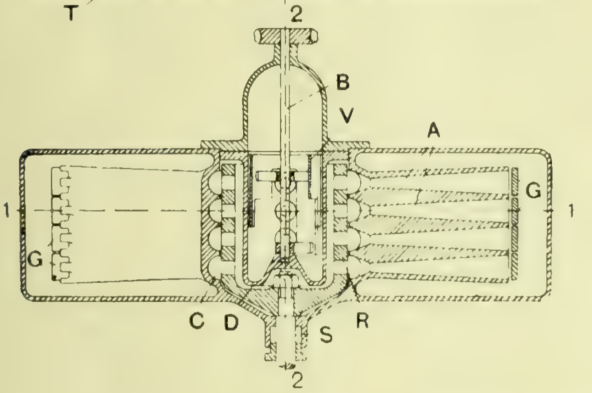


FIG. 3.

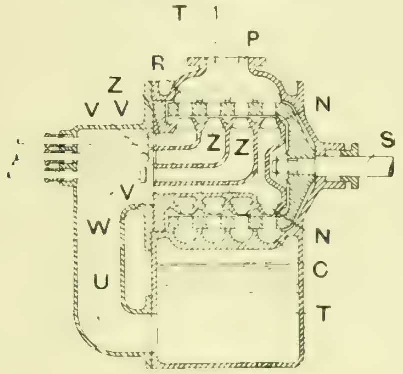


FIG. 4.

WEIR'S APPARATUS FOR EXHAUSTING OR COMPRESSING AIR.

means. Inside the rotor is located a drum D; water being supplied to the interior of the drum by the duct U. The drum is provided with nozzles or apertures N, adapted for admitting water to the turbine rotor. The turbine rotor is adapted to rotate within a chamber C to which air is admitted by the port P. The water supplied to the turbine rotor by the nozzles N is projected into the nozzles A, and drives the air from the chamber C into and through the nozzles A, which are suitably shaped and suitably located with respect to the nozzles N, and with respect to the speed of rotation of the turbine rotor and the design of the turbine buckets. One discharge nozzle A is provided for each water admission nozzle N. A valve V is provided for controlling the supply of water to the nozzles N. This valve is so constructed that one nozzle N of each row is always open, but the other nozzles are open or closed according to the angular position of the valve which is mounted on the shaft B and is adapted to be actuated by means of the worm and worm wheel shown. Any number of nozzles from one to four of each row can be open at a time. The valve V, which is of hollow cylindrical form and concentric with the turbine rotor, is shown as being located inside the drum D, but it may obviously be arranged on the outside of the drum. Moreover, the valve may be constructed and adapted to act by an axial, instead of a rotational, movement, or by a combined rotational and axial movement.

In the modified construction shown in Fig. 4, lift valves V are provided in place of a single hollow cylindrical valve. These valves control the admission of water to the passages Z respectively. Each of these passages serves to convey the water to a pair of nozzles N, that is, to one nozzle of each row. The passage W which serves to convey the water to the end nozzles is uncontrolled. In both constructions the water supply for the nozzles N is drawn from the tank T, the walls of which are formed integrally with the walls of the chamber C; and the water is discharged by the nozzles N back to the tank. To prevent the return of air or water through the nozzles A, when the water-admission nozzles N are out of action, valves G are provided at the ends of the nozzles A. The discharge ends of these nozzles may be arranged below the level of the water in the tank T.

NEW TYPE OF ELECTRIC TRAMCAR.

To avoid the delay which at present occurs at all important stopping places on tramway routes, a new type of electric car is being introduced by the tramways department of the Liverpool Corporation for use on their lines. At the present time passengers entering and leaving the cars have to use the same platform, the same entrance and exit to and from the lower deck, and the same staircase for the upper deck. This is obviated in the new cars by the provision of two stairways and a separate entrance and exit, so that the streams of in and outgoing passengers never come into contact with one another. The new cars, of which there are two types, single truck and bogie truck, have been designed by Mr. C. W. Mallins, the general manager of the Liverpool tramways, and are so arranged as to lend themselves readily to the collection of fares on the "pay-as-you-enter" system. On the single-truck car the platforms and doors are in the usual place, at either end, but the platforms are a good deal longer than has been usual. Passengers enter at the back of the platform and go straight through to the inside of the car or up the first of two spiral staircases of the ordinary type. These passengers are separated by a barrier from the people leaving the car, who use the other staircase in descending from the top deck and leave the platform by a side gateway. On the bogie-truck car the platform is placed in the centre, and is entered from the left side only, and is divided in this case into three parts by barriers and gates, which are controlled electrically by the conductor. There are three gateways opening on to the street, and passengers entering by the middle one have a clear passage to either half of the lower deck or upstairs by the stairway which is reserved for them. Passengers leave the car on either side of this entrance, and have a clear passage whether from upstairs or down. Only one of each type of car is at present running, but we understand that they will be adopted, as the old stock wears out, throughout the service.

Large Locomotive for the Great Central.—What is claimed to be the most powerful locomotive in Great Britain has been constructed by the Great Central Railway at their Gorton Works, and will be used to haul both heavy goods and passenger trains at express speed. The cylinders, which are inside the frames, are 21½in. diam. and 26in. stroke. The boiler is 5ft. 6in. diam., 17ft. 3in. in length, and weighs over 20 tons. The engine and tender in working order totals over 122 tons.

THE STRENGTH OF GEAR TEETH.*

BY GUIDO H. MARX.

THE teeth of gear wheels when transmitting power are individually subjected to an action akin to that applied to a beam fixed at one end, with a load somewhere between the fixed and the free ends. All standard formulæ or diagrams for the proportioning of such teeth therefore involve a factor

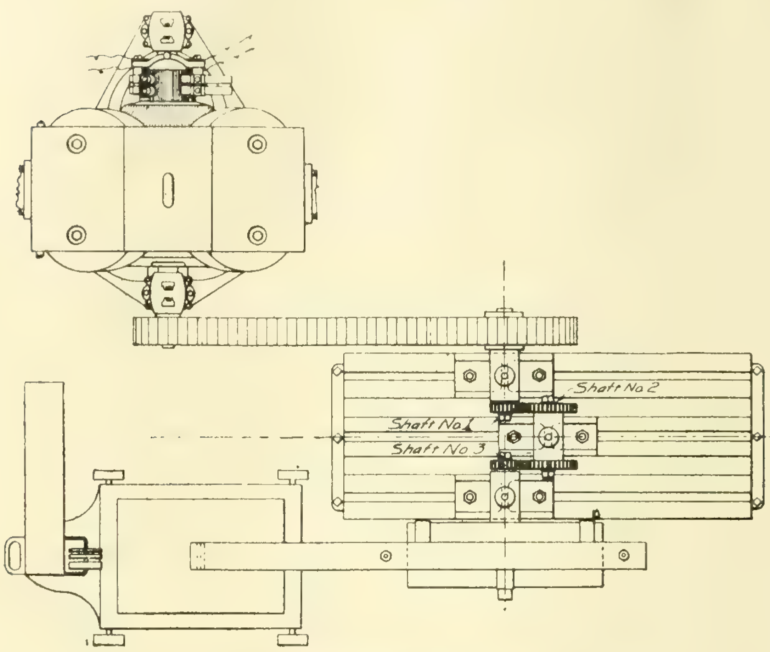


FIG. 1.—PLAN OF APPARATUS FOR TESTING GEAR WHEELS.

representing the allowable unit fibre stress in a cantilever beam subjected to a bending moment. The experiments described in this paper were undertaken with the primary purpose of throwing some light, if possible, upon the question of this allowable unit fibre stress for cast-iron gear teeth under operating conditions, since definite data upon this point have been lacking, particularly with reference to the effect of pitch line velocity. To this vital lack, attention has been called repeatedly by writers upon the subject of gearing. Thus, in Wilfred Lewis's well-known Investigation of the Strength of Gear Teeth† occurs the following statement bearing upon this matter: "What fibre stress is allowable under different circumstances and conditions cannot be definitely settled at present, nor is it probable that any conclusion will be acceptable to engineers unless based upon carefully-made experiments. In the article referred to‡ certain factors are given as applicable to certain speeds and, in the absence of any later or better light upon the subject, Table II. has been constructed to embody in convenient form the values recommended.

"TABLE II.—*Safe Working Stress S for Different Speeds.*

Speed of Teeth, Feet per minute.	100 or less.	200	300	600	900	1200	1800	2400
Cast iron...............	8000	6000	4800	4000	3000	2400	2000	1700
Steel	20000	15000	12000	10000	7500	6000	5000	4300

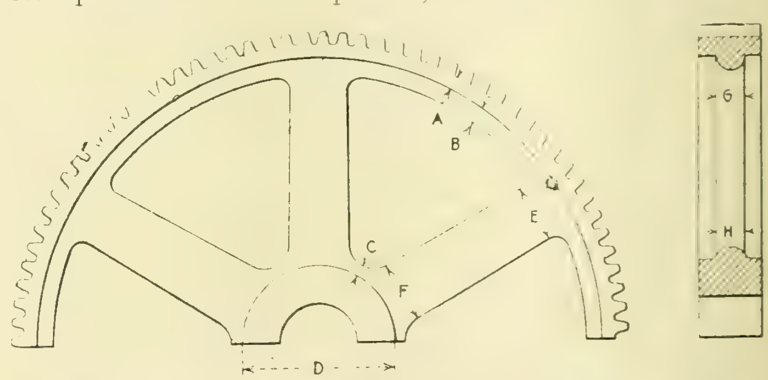
"It cannot be denied that slow speeds admit of higher working stresses than high speeds, but it may be questioned whether teeth running at 100ft. a minute are twice as strong as at 600ft. a minute, or four times as strong as the same teeth at 1,800ft. a minute. For teeth which are perfectly formed and spaced, it is difficult to see how there can be a greater difference in strength than the well-known difference occasioned by a live load or a dead load, or two to one in extreme cases. But, for teeth as they actually exist, a greater difference than two to one may easily be imagined from the noise sometimes produced in running, and it should be said that this table is submitted for criticism rather than for general adoption."

It is very evident that Mr. Lewis only offered the values of his Table II. tentatively. A careful examination of Mr. Cooper's paper fails to disclose any table from which Table II. is immediately transferred, but on page 15 of that paper will be found a series of factors, credited to E. R. Walker, Newcastle-under-Lyme, 1868, varying with the rim speed of wheels, by which the "breaking load of tooth" is to be divided. These factors are given as follows:—

$m =$ 3 for very slow speed without shock.
$=$ 4 when rim of wheel runs 3ft. per second.
$=$ 5 when rim of wheel runs 5ft. per second.
$=$ 6 when rim of wheel runs 10ft. per second.
$=$ 8 when rim of wheel runs 15ft. per second.
$=$ 10 when rim of wheel runs 20ft. per second.
$=$ 12 when rim of wheel runs 30ft. per second.
$=$ 14 when rim of wheel runs 40ft. per second.

It will be seen that these values correspond to Mr. Lewis's table if 24,000lbs. and 60,000lbs. per square inch are used for the ultimate fibre stress in flexure of cast iron and steel respectively. This is an apparent oversight on Mr. Lewis's part. While 24,000lbs. per square inch is a legitimate assumption for the unit strength of cast iron in tension, a value of at least 36,000 may be taken ordinarily for the modulus of rupture for transverse stress or ultimate unit stress in outer fibre, due to bending. That Mr. Cooper meant this modulus of rupture by "breaking stress" is obvious from pages 8 to 11 of his paper. He also quotes J. Christie as using a modulus of rupture of 36,000, with a factor of safety of never less than 4, and then under the most favourable conditions, as well-fitted gears, rigidly supported, running at moderate speed, and stress evenly distributed. For strains suddenly applied the factor of safety should be 6, and when accompanied by severe shocks and sudden reversions of strains it should be 8. With these assumptions, for cast-iron teeth, Mr. Christie would allow for safe working stresses from $\frac{36,000}{4} = 9,000$lbs. per square inch, down to $\frac{36,000}{8} = 4,500$lbs. per square inch, as contrasted to a range in Table II. of from 8,000lbs. down to 1,700lbs.

In view of the fact that Mr. Christie gives several examples from practice to sustain his position, and of Mr. Lewis's own



	A	B	C	D	E	F	G	H
60 T	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$2\frac{7}{16}$	$\frac{7}{8}$	$\frac{13}{16}$	$\frac{3}{8}$	$\frac{3}{8}$
80 T	$\frac{9}{32}$	$\frac{1}{4}$	$\frac{1}{4}$	$2\frac{7}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	$\frac{3}{8}$	$\frac{3}{8}$
100 T	$\frac{5}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$2\frac{1}{2}$	$\frac{7}{8}$	1	$\frac{7}{16}$	$\frac{15}{32}$
150 T	$\frac{3}{8}$	$\frac{9}{32}$	$\frac{5}{16}$	$2\frac{1}{2}$	$\frac{31}{32}$	$1\frac{3}{16}$	$\frac{1}{2}$	$\frac{17}{32}$

Note—All dimensions are in inches. Bore $1\frac{5}{16}$ in. Face $\frac{1}{6}$ in. in all cases

FIG. 2.—DIMENSIONS OF ARMS OF GEARS TESTED.

doubt as expressed in the foregoing quotation from his paper, of so wide a range being justified as that called for by his Table II., and of the further fact that this table was based upon a modulus of rupture much too low, it seems strange that these tentative values have been so generally accepted; and the need of adequate experimental data becomes apparent.

Mr. Cooper on page 9 of his paper says: "It is certainly necessary to know the strain that breaks a piece of projecting cast iron of given size and shape, when the stress is laid on

*Abstract of paper read before the American Society of Mechanical Engineers.

† Proceedings of the Engineers' Club, Philadelphia, 1893, vol. 10.

‡ Power Transmitting Mechanism: On the Strength of the Teeth of Wheels, J. H. Cooper, Journal of the Franklin Institute, 1879.

quietly, as well as when it is driven on with considerable velocity. It is also important to know the fractional part of the rupturing weight or stress which may be repeatedly laid on with perfect safety, to ensure the continuance of adhesion under the usual conditions of working. Upon these essential features of each case, the criteria, almost every engineer's guide book is silent."

A copy of Brown & Sharpe's Treatise on Gearing gives the only data he recalls having seen of cut gears tested to rupture under running conditions. On page 118 is the following: "We give a few examples of average breaking

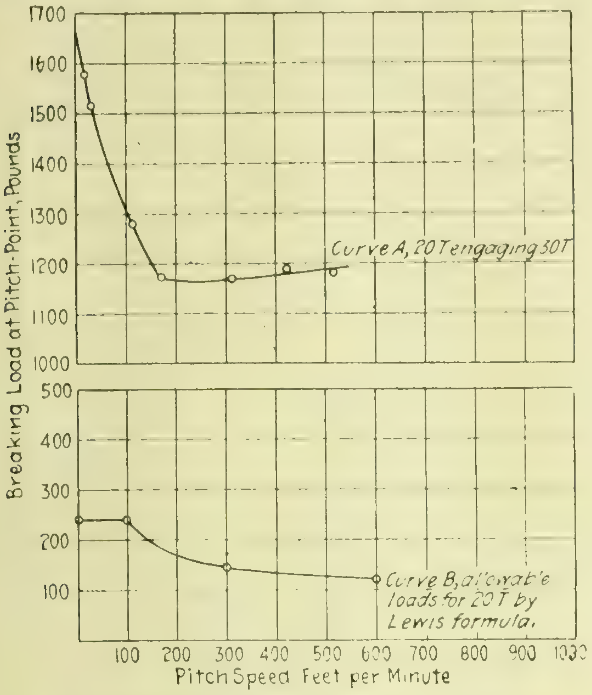


FIG. 3.—RESULTS OF TESTS WITH 20-TOOTH PINIONS.

strain of our combination gears, as determined by dynamometer pressure taken at the pitch line.

Diametral Pitch.	Face.	No. of Teeth.	Revs. per Minute.	Pressure at Pitch Line.
10	$1\frac{1}{16}$	110	27	1060
8	$1\frac{1}{4}$	72	40	1460
6	$1\frac{9}{16}$	72	27	2220
5	$1\frac{7}{8}$	90	18	2470

"If we take a safe pressure at one-third of the foregoing breaking strain we shall have for 10 pitch $353\frac{1}{3}$lbs. at the pitch line; 8 pitch $486\frac{2}{3}$lbs. at the pitch line; 6 pitch 740lbs. at the pitch line; 5 pitch $823\frac{1}{3}$lbs. at the pitch line."

In order to add to the available data concerning the strength of modern, cut, cast-iron gear teeth under operating conditions, the writer had a special apparatus, Fig. 1, constructed. It consists of a baseplate carrying three adjustable bearings. The motor, a 25 h.p. 220-volt, direct-current machine, is connected by a Morse chain to shaft No. 1. Shafts No. 1 and No. 2 are connected by a pair of cut-steel change gears of 8 diametral pitch which can be varied to give a wide range of velocity ratios. Shafts No. 2 and No. 3 are connected by the cast-iron cut gears to be tested. On the outer end of shaft No. 3 there is a flanged, water-cooled brake wheel carrying a prony brake. The arm of the brake rests, by means of a steel knife edge and plate, on a platform scale. Each bearing is provided with a sight feed lubricator. The measurement of the efficiency of transmission not being the object of the experiment, the friction of the bearings is neglected. The only effect of this is to make the computed breaking load of the teeth a very little less than its real value in each case. By means of the slotted baseplate and the tongues on the bottom of the bearings, the latter can be slid into place, the gears accurately meshed without binding or backlash, and then securely held by means of two square-head bolts to each bearing. The Morse chain is lubricated with a graphite and grease mixture, and the gears, both steel and cast iron, with ordinary thick grease lubricant which was also freely used on the brake. Before starting each run a wooden guard was placed over the gears to be tested. That this was not a useless precaution was indicated by the fragmentary condition of the gears, particularly those having arms, at the conclusion of many of the runs.

The tests were made in the mechanical laboratory of the Leland Stanford Junior University. For each run the motor was started with zero load applied by the prony brake. The scale weights were then set at the lowest load and the brake tightened until the scale beam floated. Simultaneously the rate of rotation was observed with a tachometer which was calibrated upon completion of the tests and the necessary slight corrections made in the computed results. Calibration of the scales showed them to be entirely correct throughout the range used. Increments of load on the scale began at 5lbs. each while the load was low, and were diminished to 2lbs. and 1lb. as the probable breaking load was approached. The unexpectedly high breaking strength shown by the teeth*, particularly at the higher velocities, made it impossible to break the gears at pitch speeds much exceeding 1000ft. per minute with this apparatus. At the higher speeds the teeth were capable, without rupture, of transmitting all of the power the motor could develop.

The gears tested were all 10 diametral pitch, cast-iron, $14\frac{1}{2}°$ involute, purchased of the Brown & Sharpe Manufacturing Company without intimation of the special purpose for which they were intended, and were of the ordinary stock proportions. The width of face in all cases was $1\frac{1}{16}$in. The 20 and 30-tooth gears were solid, the 40-tooth webbed, and the others each had six arms. The twenties and thirties had a bore of $1\frac{1}{16}$in. and a $\frac{1}{4}$in. keyway. The rest had a bore of $1\frac{5}{16}$in. and a $\frac{5}{16}$in. keyway. The general proportions of the arm gears are shown in Fig. 2.

The main tests were conducted in two series; the first being made in 1911 with single observations under each set of conditions; and the second, made in 1912, being planned to cover the ground more completely, with the further intention of making three runs in each case under identically the same conditions in order to eliminate errors of observation and of variable material.

Fig. 3 shows graphically the results of all the foregoing tests involving 20-tooth pinions. Abscissæ are pitch-line speeds in feet per minute, and ordinates are forces at the pitch point equivalent to the breaking loads in pounds. This equivalent breaking load is, of course, equal to the net brake load at rupture by brake arm divided by the pitch line radius of gear on brake shaft. Curve A is drawn representing the

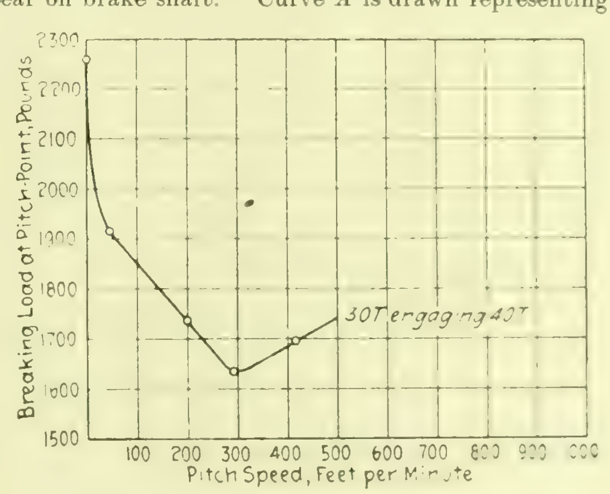


FIG. 4.—RESULTS OF TESTS WITH 30 AND 40-TOOTH GEARS.

results of all tests with 20 and 30-tooth gears in mesh. As there were several observations taken for each pitch speed, the numerical average of the equivalent breaking loads was taken for each set, and the curve drawn through these average points as near as might be.

In Fig. 3 the curve was extended by inference to the zero velocity line. It will be noted that this breaking load curve falls off with increase of speed up to a pitch velocity of something less than 300ft. per minute and then apparently starts to rise again as though the maximum percussive effect had

* Preliminary calculations had been based upon the Brown & Sharpe figures quoted above.

been passed. This fact, and the further one that within the limits of the actual tests the range of average breaking load was only from 1,579lbs. at 19·4ft. per minute down to 1,169lbs. at 312·7ft. pitch velocity, about 25 per cent., are two of the most striking points appearing in this investigation.

These phenomena might be questioned on the score that all of the 20-tooth gears but one broke entirely apart as well as having teeth stripped. But Fig. 4 shows the same general form for all tests involving 30 and 40-tooth gears in mesh; and in this case there can be no question of anything but the strength of the teeth themselves, as it was only at the teeth that any of these gears broke.

It is an unfortunate fact that the limit of the motor's power was such as to make it impossible to rupture gears at higher speeds, thus enabling us to follow the curve and observe whether the apparent rise in breaking strength continued with increase in pitch speed. No attempt has been made to make this a smooth curve; the points corresponding to the averages obtained by experiment have merely been joined.

It is clear, however, even from these somewhat limited experiments, that the impact or percussive effect with increase of speed is not nearly so great, with these modern, accurately cut gears, as has commonly been supposed. In both cases the curves show that the minimum breaking strength (at a pitch speed of about 300ft. per minute) is more than seven-eighths that at a pitch speed of about 100ft. per minute and more than seven-tenths that at zero pitch speed. And it is not theoretically impossible that the breaking load actually rises with increase of speed, after a certain critical speed has been passed, until it would approximate the static breaking load if it were not for the increasing tendency of the teeth to tear loose due to centrifugal force. At an infinite speed the repetitive stress would become a continuous one. As curve A, Fig. 3, shows the actual breaking strength of 20 teeth, 10 pitch, cast-iron gears at different speeds, it is interesting to compare with this the allowable loads for such gears computed for the same speeds by the Lewis formula.

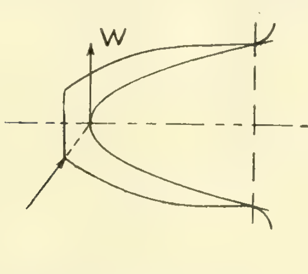


FIG. 5.—LINE OF FORCE AS ASSUMED IN LEWIS FORMULA.

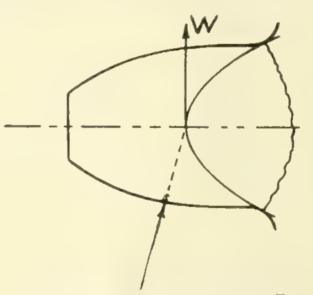


FIG. 6.—LINE OF FORCE AS DETERMINED BY ACTUAL FRACTURES.

$$W = s\ p\ f\ \left(0{\cdot}124 - \frac{0{\cdot}684}{n}\right)$$

$s = 8{,}000$ for 0 to 100ft. per minute.

$W = 8{,}000 \times 0{\cdot}31416 \times 1{\cdot}0625 \times 0{\cdot}90 = 240$ .... (1)

$s = 4{,}800$ for 300ft. per minute.

$W = 4{,}800 \times 0{\cdot}31416 \times 1{\cdot}0625 \times 0{\cdot}90 = 144$ .... (2)

$s = 4{,}000$ for 600ft. per minute.

$W = 4{,}000 \times 0{\cdot}31416 \times 1{\cdot}0625 \times 0{\cdot}90 = 120$ .... (3)

Curve B, expressing these, is shown at the bottom of Fig. 3. The discrepancy between the two curves is obvious. They do not even have the same general form.

Mr. Lewis's formulæ and tables were intended to provide a factor of safety of 3 for pitch speeds of 100ft. per minute or less, of 5 for 300ft., and 6 for 600ft., the differences being intended to cover presumed increases in impact effect. Using Mr. Lewis's accepted formula for 15° involute teeth as being applicable to the Brown & Sharpe standard 14½° involute teeth, namely,

$$W = s\ p\ f\ 0{\cdot}124 - \frac{0{\cdot}684}{n}$$

W = working strength of tooth.
s = working stress of material per square inch.
p = pitch of teeth in inches.
f = face of teeth in inches.
n = number of teeth.

Table I. has been prepared to show the relation between the computed working strength and the actual breaking loads for the 20 and 30-tooth gears within the range of these experiments, as shown by the plotted curves on their legitimate inferential extension.

TABLE II.—*Velocity Coefficients.*

Pitch Velocity, Ft. per Min.	000	100	150	200	300	400	500
Ratio $\frac{\text{Breaking Load at Given Velocity}}{\text{Breaking Load at Zero Velocity}}$ Data from Fig. 4.	$\frac{1660}{1660} = 1{\cdot}0$	$\frac{1310}{1660}$ 0·789	$\frac{1205}{1660} = 0{\cdot}725$	$\frac{1165}{1660} = 0{\cdot}702$	$\frac{1165}{1660}$ 0·702	$\frac{1175}{1660} = 0{\cdot}707$	$\frac{1185}{1660}$ 0·712
Ratio $\frac{\text{Breaking Load at Given Velocity}}{\text{Breaking Load at Zero Velocity}}$ Data from Fig. 5.	$\frac{2260}{2260} = 1{\cdot}0$	$\frac{1850}{2260}$ 0·819	$\frac{1790}{2260} = 0{\cdot}792$	$\frac{1735}{2260} = 0{\cdot}768$	$\frac{1640}{2260} = 0{\cdot}726$	$\frac{1680}{2260}$ 0·743	$\frac{1740}{2260}$ 0·770
v—Velocity Coefficient, Safe	1·00	0·80	0·75	0·72	0·70	0·68	0·66

When the actual breaking loads under running conditions have been determined, as they have in the above cases, the results provide the allowances for pitch-speed variations and it is difficult to see any reason for not using a uniform factor of safety for conditions which are uniform in other regards than pitch speeds, to provide for the possibilities of faulty material, poor alignment, sudden applications or reversals of stress, and possible overloads. Just how great this factor need be is a question to be settled by the designer in each individual case. But in any case it would be a true factor of safety and not a factor of ignorance.

Mr. Lewis's Table II. may be looked upon as a table of factors representing a combination of the modulus of rupture, a factor of safety, and a coefficient depending upon velocity. It would seem better to separate these. The value of the modulus of rupture is discussed below. For values to be taken for the factor of safety the writer agrees with Mr. Christie as quoted on page 80.

TABLE I.—*Relation between Computed Working Strength and Breaking Loads 20 and 30-tooth Gears.*

	Pitch Speed Ft. per min. 0	100	300	600
20T in mesh with 30T				
Computed working load, Lewis's formula..	240	240	144	120
Actual breaking load, tests	1660	1310	1165*	1165*
Corresponding factor of safety	6·9	5·5	8·1	9·7
Working load, factor of safety = 4	413	340	290	290
30T in mesh with 40T				
Computed working load, Lewis's formula..	270	270	163·2	135
Actual breaking load, tests................	2260	1850	1640	1640*
Corresponding factor of safety	8·4	6·9	10	12·2
Working factor of safety = 4	565	463	410	410

*Neglecting apparent rise in curve.

The values of the coefficient to provide for the effect of pitch velocity v can be determined from the results of the tests shown in Fig. 3, curve A, and Fig. 4. These results are expressed in Table II., together with a series of values of v based upon them and so selected as to lean toward the side of extra safety.

To check the material of the gears used in these tests and to determine whether it was normal or of exceptional strength, 24 test specimens were cut from 12 of the 30-tooth gears, selected at random. These specimens were about ½in. thick, 1⅛in. wide, and 2¼in. long. Seventeen similar specimens were

cut from castings made in the university's foundry and known to be of ordinary composition and quality. The specimens were all tested in flexure with the load applied at the middle of a span of $1\frac{3}{4}$in. The modulus of rupture of the gear material test pieces was 38,737lbs., while that of the check specimens was 39,049lbs. It is legitimate to conclude that the material of the gears used in these tests, while of first rate quality, was not unusual or exceptional. The results of the tests may therefore be accepted as representing typical material. In general a value of 36,000 may be reasonably used for the modulus of rupture for cast-iron gear teeth.

(To be continued.)

REGULATIONS FOR APPRENTICES.

THE following regulations have been issued by Messrs. Mather and Platt, Ltd., Manchester, for the admission and control of apprentices in their works:—

Apprentices are admitted into the works in accordance with the following regulations. They are divided into three classes:—

First Class.—Boys, of not less than 15 years of age, are admitted as "Trade Apprentices" with the object of becoming "Tradesmen" on reaching 21 years of age. They must have passed Standard VI. at a primary school, and have attended a continuation school, or produce other proof of having had a satisfactory elementary education, and must be capable, if required, of satisfactorily answering an elementary examination paper in arithmetic. They are required throughout the whole term of their apprenticeship to attend evening classes at the Manchester or Salford Schools of Technology, or other approved schools, and in certain cases, selected entirely by merit, are allowed to attend the special day courses for apprentice engineers at the Manchester School of Technology, but this privilege is only granted with the express permission of the works manager, and is restricted to those boys who can show that they will derive full benefit. No deduction is made from wages for the time spent at these classes. Trade Apprentices are paid wages from the commencement of their employment, according to the uniform scale for the time being in force, and are advanced annually, if conduct and progress both in the works and in the classes have been satisfactory.

Second Class.—A limited number of youths of not less than 17 years of age, able to submit a satisfactory introduction and references, and of giving proof of a thorough general education at a secondary school or public school, by examination certificates or otherwise, are admitted into the works from time to time as circumstances permit, with the object of obtaining practical training in different branches of engineering. Those who have had a recognised course of technical training at a technical school, or have obtained distinction at a public school or grammar school, have preference in selection for this class. A knowledge of French, German, or other modern languages is considered an additional qualification. Youths in this class are transferred from department to department, so as to obtain as wide an experience as possible, but subject always to the shop conditions at the time permitting of entry into a particular department, and to the express permission of the works manager. Mather & Platt consider that the best training is obtained by starting in the foundry, and then passing to the machine tools, fitting, and assembling, and this course will be followed as circumstances permit. As far as possible all youths in this class will spend some time in one or other of the test-rooms, and in the drawing-office. All youths in this class enter the works for a probationary period of six months, during which time they do not receive any wages. From the end of this period they will receive a weekly wage of 10s., and thereafter, up to the end of their apprenticeship, such wages as may be arranged by the management. All youths in this class are required as a condition of their employment to continue their technical education, by attendance at evening classes at the Manchester or Salford Schools of Technology, or at the University; and in certain cases, selected entirely by merit, are allowed to attend the special day courses for apprentice engineers at the Manchester School of Technology, but this privilege is only granted with the express permission of the works manager, and is restricted to those youths who can show they will derive full benefit. No deduction is made from wages for the time spent at these classes. Every youth admitted into Class II. must obtain a letter from his parents or guardians undertaking that they will not remove him during the time arranged for his apprenticeship without the consent of his employers.

Third Class.—With a view to affording facilities for practical workshop training, a very limited number of young men of not less than 20 years of age, who have passed a complete course of technical training at a technical school, or who have obtained a degree or diploma in engineering or science at a University, are admitted into the works from time to time as circumstances permit. Anyone applying for admission into this class must have a satisfactory introduction and references, and must submit a complete statement of their educational career and attainments. It must be understood that selection is made, having regard to the educational qualifications that a candidate is able to submit, and that great importance is attached to a candidate having a thorough knowledge of French, German, or other modern language. All men in this class enter the works for a probationary period of six months, at the end of which time there is no obligation to remain, or on the part of the employers to continue the employment. If it is then agreed to continue, the candidate must agree, in writing, to remain in the employment of Mather & Platt for the further period arranged. During the probationary period of six months no wages are paid. The remuneration during the further period will be subject to arrangement according to the merits of each case. Although Mather & Platt cannot undertake any obligation that men in this class shall spend any specific time in any particular department, the management, as far as possible, will select the department or shops so as to give the best possible practical engineering training suited to the attainments and capabilities of each man, and not with a view to obtaining skill in any particular handicraft.

GENERAL.

Apprentices of all classes are subject to the usual works regulations and must keep shop hours, which are as follow: Monday to Friday inclusive, 8 a.m. to 12-30 p.m., 1-30 to 5-50 p.m.; Saturday, 8 a.m. to 12 noon. Mather & Platt in no case charge any entrance fee or premium, nor indenture any apprentice, nor undertake to continue the employment of any apprentice.

All applicants must be of sound constitution, and must, if required, produce a medical certificate showing their physical fitness for the work.

Mather & Platt desire to draw attention to the age limit of 15, below which they will not in future admit any apprentice. This age has been fixed in order that boys may have the advantage of some instruction in elementary science at a continuation school before commencing work in the shops.

A member of the staff is deputed to keep a register of all apprentices, their educational record, the time spent in each department, the classes attended, and the reports of the masters. Apprentices are encouraged to consult with him from time to time as to any change in their employment which appears desirable, and he will endeavour accordingly to arrange it with the works manager. He will advise apprentices as to the classes that will be most useful for them to attend, and will pay the fees for the session, for the classes selected and approved.

The Principals of the technical schools and of other schools whose classes are attended by Mather & Platt apprentices are invited to report at frequent intervals on their attendance and progress.

No holidays other than the usual works holidays are granted to any apprentice, except with the express permission of the works manager.

Mather & Platt wish it to be understood that they are able to accede to only a very small proportion of the applications made to them for entry into Classes II. and III., and that in making the selection of those to whom the privilege is extended, they are primarily guided by the intention of selecting those students whose antecedents, physical fitness, character, and educational attainments are likely to fit them for permanent posts on the staff. They also desire to point out that, although the above regulations primarily apply to works employment, nevertheless it has always been the practice of Mather & Platt to select as far as possible those who have had practical training in the works for the more important posts in the office pertaining to the commercial side of the business, and it is their intention to continue such selection from the several classes of works apprentices.

BREAKDOWN TESTS OF METALS.*

BY O. BOUDOUARD.

RUPTURE of a metal is produced not only when the breaking stress is applied in one single instance, but also when the metal is submitted to tensions or compressions decidedly smaller than the breaking stress, all being of the same sense and repeated a sufficient number of times; or, again, when the metal is submitted to still smaller tensions and compressions, provided that they act alternately in opposite senses. Now the resistance of metals to alternating stress is an essential feature for a great many industrial applications, in particular for parts of machines in which the stress changes at every instance in sense and in magnitude.

Mr. A. Guillet, Secretary of the Faculté des Sciences, in Paris, established the two following facts two years ago, while studying the vibratory movements of metals: (1) Under the same experimental conditions the damping of the vibrations of a U of soft iron is about three times greater than that of a U of soft steel; (2) the viscosity of the metal varies in accordance with the deterioration of the metal owing to the repetition of the alternating stress. Prof. Henry Le Chatelier directed the attention of scientists and engineers to the problem which Guillet had attacked; the measurement of the damping indeed revealed a novel property of matter which was directly connected with the intimate constitution of matter, and the new method of testing—apart from its being economical and rapid—should offer the very great advantage that it follows the deterioration of the metal as it proceeds, because this deterioration is manifested by a rapid and very considerable increase in the rate at which the damping of the vibratory movement takes place.

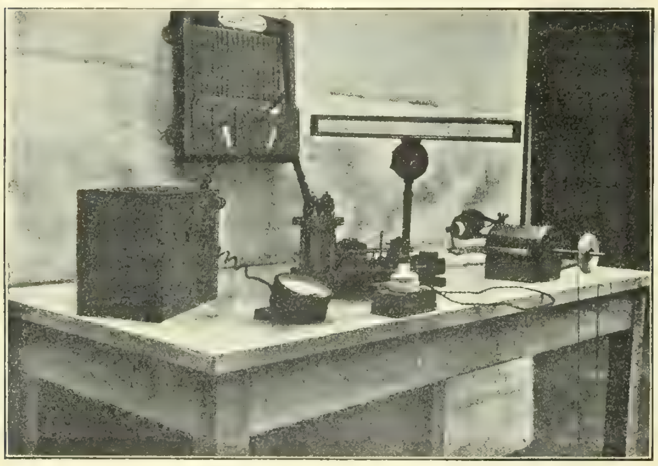


FIG. 1.

The use of the tuning fork, as suggested by Guillet, is not absolutely indispensable for this kind of testing. It is, on the contrary, preferable to experiment with rolled rectangular bars, analogous to those which the works supply. The simplest arrangement is to grip similar bars, 20 cm. to 30 cm. in length, in a massive and rigid support; the practical difficulty is, however, to secure that the mounted bar has no free play, and that the mounting has no influence upon the damping.

Description of the Apparatus.—The apparatus is intended to produce vibrations in the horizontal plane (Fig. 1). The bar of metal to be examined (Fig. 2) has the following dimensions: width, 1 cm.; thickness, 0·6 cm.; the bar oscillates over a length of 27 cm. It is fixed by one of its extremities in a sort of vice S rising perpendicularly from a bench B which is provided with a longitudinal groove along which the electromagnet E slides which attracts the bar or rod. By the side of the bench, which is independent of the vice, is mounted a small brass table T, likewise grooved, being provided with two grooves along which the contact slides which is controlled by the vibrating bar. The vice which holds the metallic bar resembles a small rolling mill for hand operation, the cylinders of which have been replaced by jaws of hard steel which have been most carefully adjusted. These jaws form the seat for the bar in question (Fig. 3). The lower jaw M is fitted with two studs G, which penetrate into two holes drilled into the base of the small mill so that M is firmly fixed; the upper jaw M′ bears the pressure of the two screws of the mill. The vibrating rod is by these means held immovable over a length of 5·7 cm. The vice is solidly fixed to a table (of slate) by means of two angles of soft iron fitted with screw bolts. The bench B is secured in a similar way, and the table makes one body with the walls of the building. It is indeed very important for this style of experiment to realise an absolute rigidity of the support of the vibrating reed, lest the vibrations be affected by external causes. The apparatus, which I have installed at the College de France, seems to satisfy this condition. By watching a horizontal mercury surface one can ascertain that vibrations of very large amplitude do not affect the support more than very slightly; anyhow, the mounting of the metallic bar in the jaws of the vice leaves no free play and does not therefore play any part in the damping of the oscillating movement.

The contact by means of which the vibrations are maintained is placed at about 9 cm. from the fixed extremity of the rod. It consists of a vertical flat spring *r*, which forms the mobile terminal and which is connected with the rod by a thread *f* (of sewing cotton); against this spring *r* bears a screw V, the fixed terminal. The current interruptions are produced by the vibrating rod which actuates the flat spring *r*, because it keeps the thread *f* more or less stretched. The parts of the spring and of the screw between which the spark passes are protected by platinum; as the platinum contact on the spring disappears rapidly, it is preferable to substitute for it a blade of iron, 2 mm. or 3 mm. in thickness, which has no value and can easily be replaced. The electromagnet acts on the rod at a distance of about 10·5 cm. from the fixed end.

The current intensity can be measured at any moment by the ampere meter A, and it can be varied with the aid of the resistance R; the current is furnished by four accumulators. The circuit comprises an interrupter I which can break the current of the electromagnet at once when one wishes to study the damping of the vibrations of the metal under examination.

The maximum amplitude which is compatible with a given static intensity is immediately obtained, when the contact is so regulated that the ampere meter marks half the static intensity. A few hundredths of an ampere suffice to produce a sensible vibratory movement. When one wishes to obtain displacements of the free end of the rod corresponding to a few centimetres, a current of several amperes will be required. The distance between the lateral surface of the bar and the extremity of the core of the electromagnet is about half a centimetre.

Readings of the amplitudes are taken with the aid of a narrow slit, which is well illuminated from some source, or better, directly by the filament of an incandescence lamp; this slit is placed in the focal plane of a lens N, interposed between the transparent graduated scale and a small plane mirror attached to the end of the vibrating rod. The rays from the lamp traverse the lens, are reflected by the mirror, pass through the lens a second time, and then form an image on the scale which is in the same plane as the source of light. The mirror is fitted into a brass sheath which is pushed under hard friction over the free end of the rod. The lens is placed at a distance of about 1 cm. from the mirror. With this arrangement deflections of the image of 30 cm. and more can easily be obtained by using lenses of different focal lengths and by varying the distance between the mirror and the lamp. The amplitudes at different moments or, at anyrate, the total length of the damping period can be measured with the aid of a chronometer; but the operation is very delicate. In order to ensure a greater accuracy and, above all, to avoid all personal errors, it will be more convenient to photograph the damping curve on a cylinder which is turned at a known rate, once per minute *e.g.* One can at the same time register, once for all, the curve of the oscillations of a tenth-of-a-second tuning fork; in this manner the length of the damping period and the number of rod vibrations per second can be recorded. I have made use of a recording cylinder after Richard, 12 cm. in height, on which a sheet of very sensitive gelatine-bromide paper is wound. The luminous slit is constituted by the

* Paper read before the International Association for Testing Materials.

filament of a Nernst lamp; the intersection of the vertical luminous image with the horizontal slit, guided along a generatrix of the second cylinder surrounding the first moving cylinder, determines the luminous point which acts on the photographic paper. Nernst lamps are to be recommended, since the vibrations are rapid both in normal movement and during the damping. Other lights are hardly powerful enough completely to register the normal vibrations and the damping curve.

Course of an Experiment.—In each series of tests one registers the damping curve of the bar before it is made to vibrate, and then the damping curves at variable time intervals up to the moment of rupture; the different diagrams are afterwards compared with one another. The

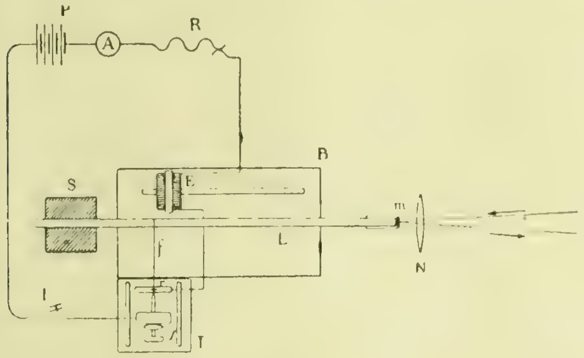


FIG. 2.

long-duration tests take place in periods of unequal lengths; sometimes the metal remains at rest for one day or several days between the recording of two successive damping curves.

When the curve is registered by a Richard apparatus which makes one revolution per minute, the length of the successive elongations cannot easily be measured with sufficient precision. We obtain in fact the curve-envelope of the vibratory movements without being able to distinguish the individual vibrations, and we can thus only determine the length of the damping period. When we then replace the clockwork, which makes the cylinder complete one turn per minute, by another gearing which increases the speed about five-fold, then the vibratory movement itself will be recorded, and the photograph allows us to determine both the amplitudes and the number of vibrations with sufficient accuracy. This gearing is very simple: an aluminium pulley is mounted on the shaft of the recording cylinder; in the hollow of the pulley lies a cord which supports an iron disc at its one extremity and a counterweight at the other; in its fall the disc makes the recording cylinder take part in its movement, and this movement is kept regulated because the fall takes place within a test tube filled with water, the diameter of the tube being a little larger than that of the disc. In this way the recording cylinder is turned at a fairly uniform rate, which can be adapted to the experiments. When a curve is to be recorded, the disc is raised to its upper position; it is then left to itself for a few seconds, after the shutter of the Richard apparatus has been opened; the current of the electromagnet is now interrupted by means of the device I have mentioned above. When the pulley has described one turn, which is easily ascertained with the aid of a mark, the shutter is lowered. One has afterwards only to develop the photograph.

In the photographs thus obtained the distance between the extreme points of the elongations constitute the amplitudes to be measured, and it is just at these points that the action of the light on the sensitised paper is maximum because the velocity of translation of the mirror is there zero. The amplitudes are measured with the help of a glass mirror which bears a scale divided into half-millimetres; this mirror is moved over one vibration curve after another, and readings to a quarter of a millimetre can easily be taken. In order to enable the experimenter to count the number of the vibrations, especially near the end of the damping period, the mirror further bears a series of equi-distant parallel lines by means of which the mirror can be shifted through a known distance, parallel to itself, starting from a reference point previously marked on the diagram.

The total elongation of the free end of the vibrating rod is 3·5 cm. or 4 cm., which corresponds to an angle of deflection of 6° or 7° between the extreme positions. About 30 double vibrations are counted per second. According to Chladni an oscillating rod having one end fixed and the other end free should give the note ut_1 = 32·625 double vibrations.

All the tests have been conducted in the air and at ordinary temperature. One has, however, to ask oneself whether the resistance of metals to alternating stress is not a temperature function. Very often metals are doing work at more or less elevated temperatures, and we know that the rupture of parts which are heated by the steam in engines cannot be explained by a diminution of the toughness. Vibration experiments are now being conducted on hot metals in accord with the Unieux Steel Works.

Results of the Experiments.—The tests were made with the following carbon steels, which Messrs. Schneider & Co. had placed at my disposal.

No. 1 .... Puddle iron.
No. 2 .... Basic Martin steel, extra soft.
No. 3 .... Crucible steel, about 0·3 per cent. of C.
No. 4 .... Crucible steel, about 0·6 per cent. of C.
No. 5 .... Crucible steel, about 1·0 per cent. of C.

As regards the precision of the method, I have investigated whether it was always possible to secure the same experimental conditions with regard to the clamping of the bar between the jaws of the vice on the one hand and the fixing of the vice to the table on the other. The discrepancies which I observe with respect to the first point are always distinctly smaller than those shown by the diverse damping curves of the same metal; as regards the second point a defective fixing is at once recognised as such, because the damping of the vibratory movement is then almost instantaneous. The influence of the air resistance on the vibrations does not modify the general conclusions of this research; it produces an increase in the value of the decrement amounting to about 10 per cent; this figure is generally accepted. The results may be summarised as follows:—

Designation of the metal.	Time during which the vibrations continued, up to rupture.	No. of vibrations.
No. 1 annealed	18 hrs. 45 min.	1,995,000
2 annealed	11 ,, 45 ,,	1,215,000
3 annealed	13 ,, 15 ,,	1,431,000
— hardened	14 ,, 15 ,,	1,512,000
4 annealed	6 ,, 15 ,,	648,000
— hardened	1 ,, 25 ,,	153,000
5 annealed	3 ,, 25 ,,	369,000
— hardened	5 ,,	9,000
— hardened and reheated ..	no rupture after 26½ hrs. >	2,862,000

In all these tests rupture of the metal is finally produced by the repetition of a great number of alternating stresses which were smaller than the breaking strength. It is known that a piece of metal, when submitted to a repetition of alternating stress, rising from zero as lower limit to a certain predetermined upper limit, will not fail even after an unlimited number of applications of the stress, provided the upper limit remains below the primitive limit of elasticity; as long as this limit is not exceeded, the security of the part is not endangered. It is easy approximately to calculate the force corresponding to the action of the electromagnet capable of imparting to the test bar an equivalent flexion, and also to determine experimentally the practical elastic limit of the metals which are tested by vibrations; and this investigation will show that the bars have been broken, although they were merely subject to stress below their elastic limit.

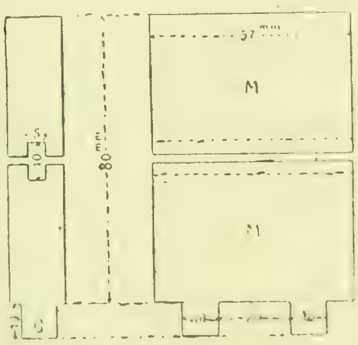


FIG. 3.

Finally, with respect to the question of the damping of the vibratory movement, the results—contrary to what might have been expected when the research was started—do not on the whole appear to establish in any decisive manner that the

metal does undergo noteworthy transformations before breaking down, and that its alteration could easily be followed by comparing the rates of the damping of the vibratory movement at different instances. Nevertheless, we can keep count of the variations in the damping by determining the mean logarithmic decrement in each case; we then come to the same results as when considering the damping curves constructed by taking as co-ordinates the number of vibrations and the logarithms of the elongations.

Conclusions. — In testing different specimens it is easily possible to ensure the same experimental conditions and to obtain measurements which are comparable with one another. One need not fear any defect in the gripping of the screws which fix the support of the frame to the table; for any such defect would immediately reveal itself by the character of the damping curves which would entirely differ from the other damping curves. The time necessary for the rupture of a metal under continuous vibratory movement comes out practically the same in the different experiments. In the case of steels containing about 0·3 per cent. of carbon, not of the

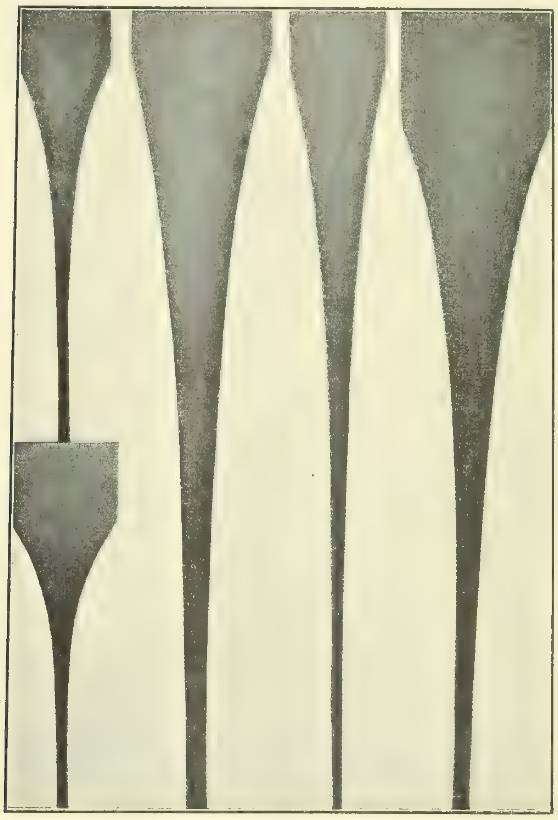


FIG. 4.

same origin but of the same chemical composition, it is found that the breakdown tests take from 12½ to 13¼ hours. This new method of testing metals by the study of the damping of the vibratory movement therefore admits of useful application for the purpose of determining their resistance to alternating stress.

The vibratory movement, when sufficiently prolonged, leads always to the rupture of the tested metal, and the number of necessary vibrations varies, in the case of the half-hard and of the hard carbon steels so far studied, in the inverse ratio of their carbon ratio. Puddle iron and extra-soft steel which have nearly the same composition (apart from the percentage of manganese which ranges between 0·050 and 0·400 per cent.) and which also have the same mechanical constants, show a marked difference as regards the length of time required to effect rupture; puddle iron resists much longer than the extra-soft steel. Whether the 0·3 carbon steel is annealed or hardened does not make any noteworthy difference. For the hard steel the hardening diminishes the length of the period during which the vibrations have to be maintained to effect rupture very noticeably. Reheating improves the quality of the metals considerably; a steel with 1·0 per cent. of carbon which broke after 3 hours 25 minutes in the annealed state, and after 5 minutes in the hardened state, was not yet broken after 26½ hours in the hardened and annealed condition.

All the fractures of the broken metals will offer a similar appearance. We distinguish in them, even with the naked eye, lines of separation along which the rupture appears gradually to have taken place. The size of the grains varies with the zones, and this size appears particularly exaggerated in the hardened metals. Moreover, at right angles to the edges of the broken section, lines are distinctly discernible which suggest a tearing apart; these lines are not any longer than half the smallest dimension of the bar, and they do not show any regularity.

As regards the mechanical properties, one should not overlook the great rise in the elastic limit shown by the puddle iron and the extra-soft steel after having been broken down by continued vibrations. It should also be accentuated that all the metals tried have been broken down, although they were exposed to stress that kept well below the elastic limit.

The variations in the damping of the vibratory movement are in general too small to characterise a metal at different moments of the test. If it were possible to predict the exact moment of rupture, the comparison of the curve obtained a few minutes before the rupture and of the initial curve would furnish further interesting information concerning the state of the metal which has been vibrated; this seems to follow from the tests made with the metals 1 (annealed) and 4 (hardened), in which the damping curves taken 15 and 25 minutes before the rupture indicated that the damping had increased by about 50 per cent. above its initial value. But a fixed rule cannot be laid down; for nothing is known as to any new metal, unless the experiments are multiplied at very close intervals, which would render the method very tedious. I must, moreover, point out again that I have not been able to conduct the long-duration tests which I have carried out without interruption. The metal had to remain at rest for one or several days between the registrations of the successive damping curves; might there possibly intervene some factor which would influence the final results of the tests?

As regards the annealed steels, the damping diminishes when the carbon percentage increases. When we compare the extra-soft steel with the puddle iron of the same chemical composition and of the same mechanical constants, we find for the same duration of the vibratory movement that the damping of the puddle iron is about 50 per cent. smaller than that of the extra-soft steel, but that it becomes almost equal to it a quarter of an hour before the rupture of the test bar, that is to say, 7½ hours after the soft-steel bar had already been broken. The damping of the hardened metal No. 3 is inferior to that of the same metal in the annealed state; the opposite holds for the metal No. 4 annealed and hardened. Finally, in the case of metal No. 5 the damping of the hardened and annealed metal, although it passes through a maximum, remains practically the same as that of the reheated metal.

TESTS OF HIGH-TENSION INSULATORS.

THE results of some tests of high-tension insulators were presented in the course of two papers recently read before the American Institute of Electrical Engineers. In the first paper, by Mr. L. E. Imlay and Mr. P. H. Thomas, the authors furnished the results of tests on insulators intended for a 38,000-volt line in connection with an existing line of 22,000 volts. The insulators on the latter were made of electrose with an umbrella petticoat about 12in. diam. and a second petticoat about 6in. diam. They occasionally punctured through the head from lightning. They were mounted on grounded steel pins. This failure was surprising, since they had never punctured in testing, but would flash over when wet at about 90,000 volts, 25 cycles. Apparatus was therefore arranged to test at ordinary frequency and also at very high frequency by the use of an oscillatory discharge. A transformer of 500 kw. at 750,000 volts was used, one side of transformer and apparatus being grounded. Tests made on the old insulators and upon a variety of new electrose and porcelain insulators showed that several forms of insulators which failed by flashing over upon a low-frequency test would be punctured by the high-frequency test. The voltage in the latter frequently exceeded 300,000 volts. Electrose and porcelain did not differ in their behaviour in this respect. Both petticoats were sawed off of one insulator, which then

showed no failure under high frequency at 340,000 volts in over 150 trials. It was not believed that the effect was due to heating, as in that case cutting off petticoats would not increase the resisting power. In most cases a large number of applications at high frequency was necessary before puncture took place. A significant point was that no insulator failed on high frequency on the very first shock. An estimate of the frequency of the oscillatory circuit was 1,000,000 cycles per second. A theoretical discussion was given as to the reason for the observed effects and some tests were made with special arrangements in support of this theory. The tests showed that it was desirable to include tests at high frequency in the practical work of testing insulators, at least to determine design. Such tests required large capacity and high voltage. The design of insulators to resist high-frequency discharges should include the wide separation of conducting parts from the pin and as great uniformity of electrostatic field between them as possible. Wide and thin petticoats added little to the strength. The authors decided to use wooden pins.

In the second paper, by Mr. P. W. Sothman, the results of tests carried out to determine the insulator most suitable for a 110,000-volt line were presented. Insulators were tested one at a time and also in parallel. The apparatus consisted of two 50-kw., 150,000-volt transformers in series. Electrical tests were made dry, wet, and under oil, and a mechanical test for strength was also made. The voltage was controlled by a water rheostat in the low-tension circuit. Voltage was measured by a voltmeter previously calibrated with a spark gap The voltmeter was connected to the low-tension side of an instrument transformer connected to the primary of the test transformer. Tests on six types of insulator showed that in most cases the discharge was started by a sharp corner or point of metal on the parts which held the sections together. While the link feature was advantageous from a mechanical viewpoint, it created unfavourable stresses in the air between the discs. The diameter of the pin, together with the voltage it assumed, remained the determining factor for the highest stress of the porcelain within the cap. For this reason no advantage was gained by the use of a two-piece insulator. It was advisable to have the metal parts of insulators as symmetrical as possible, presenting a smooth and even surface without projections. This suggested the ball-and-socket type of connection. Another unfavourable feature of a two-piece insulator was the impossibility of equalising the stress in the two pieces under all conditions. The use of a pin cemented into a porcelain shell looked, at first, doubtful, but had given no cause for complaint, while the link feature was a failure electrically. A European type of insulator met all the electrical requirements but not the mechanical tests. The latter point could be covered by modifications of design. This type was not ordered, however, on account of the necessity for prompt delivery. Of the others, two failed to meet the electrical requirements, one involved a faulty design and another met the electrical but not the mechanical tests. The latter, with modifications, was adopted for use. None of the types recommended by the manufacturers met the requirements of a strain insulator for the wet test. The author considered the problem of insulating high-tension transmission on lines as far from being solved, but much valuable experience had been gained. The author deprecated the use of excessively high voltages, such as a system for 145,000 volts already in operation and another for 180,000 volts, which was in contemplation. Caution should be used before adopting any high voltages. A few years ago the suspension type of insulator was supposed to have given a solution for line insulation, and the factor limiting the use of high voltage was considered to be corona and atmospheric leakage. These views needed revision. The uncertain conditions manifested in such a system were the behaviour of oil circuit-breakers, the lightning-arrester problem, and the high-tension transformers. Most of this apparatus was in the stage of development.

Fatal Boiler Explosion on a French Steamer.—According to Lloyd's agent at Fayal, Azores, a boiler explosion occurred a few days ago on board the French steamer "Madonna" while on a voyage from New York to Marseilles, resulting in five firemen being killed and one injured.

POWER REQUIREMENTS OF ROLLING MILLS.*

BY W. SYKES.

THE increasing use of electric motors for driving the main rolls in modern steel works makes the question of the power requirements of rolling mills of considerable importance to those engaged in designing such installations. The subject is one of great complexity due to the various factors controlling the power requirements, and also to the variation in operating conditions in different works. Indeed, it is hardly possible to obtain reliable information from published data, and rolling-mill practice is wholly based upon empirical knowledge gained by experience. One of the most difficult features of this problem is to determine the set of conditions on which to design the equipment. A great many superintendents are of the opinion that it is impossible to obtain, within limits, an equipment too large. This is a mistaken idea based upon past experience; it has been shown that by improvements, mainly in organisation, the output can be increased often as much as 100 to 200 per cent. over the original estimate.

With our present knowledge of rolling conditions, and in view of what has been done in the past, it should be possible to make a reasonable estimate as to how much the production of a mill may be increased in the future by improvements in the auxiliary apparatus and organisation. This is a factor which must always be considered when designing an installation; and it is here that the electrical manufacturer must often take the responsibility for assumptions as to rolling conditions altogether different from those given by the steel-mill engineers. Some of our most successful manufacturers of rolling-mill engines have based their machines upon the size required to break some part of the mill. So long as efficiency is not considered and it is not necessary to meet competition as to price, such an arrangement is ideal from the standpoint of the manufacturer, as there is never any doubt as to the operation of his part of the plant, but under existing conditions attention must be paid both to efficiency and the price of the equipment.

In the first place it must be pointed out that the size of the mill as determined by the size of pinions, or the width and diameter of rolls, has comparatively little to do with the size of motor required for driving it, as the work performed by the same size mill may vary several hundred per cent. The fundamental basis on which the size of motor must be determined is the product of the mill and the tonnage rolled. There are a great many factors entering into the proposition which must be considered. Dealing first with the product, the following are the principal, in their usual order of importance: Volume of metal displaced; method of displacement; temperature of metal; class of material; rate of displacement and size of roll.

Volume of Metal Displaced.—It is of the greatest importance to have some method of comparing the actual work done on the metal in various mills. I have used, as a unit of work, the horse-power seconds required to displace 1 cub. in. of metal. This unit of work takes into consideration only the volume displaced in the direction of rolling, and for simple work such as rolling plates, blooms, flats, &c., practically all of the metal is displaced in this way, as the displacement at right angles to the direction of rolling is negligible. In cases where the section of the pass is completely enclosed by the rolls, there is very often a side displacement which this unit does not take into consideration; but whatever system is employed, it is at present only possible to take into consideration the displacement in the direction of rolling. The unit here adopted, of horse-power seconds per cubic inch displaced, will be referred to as "specific power consumption."

Method of Displacement.—It is also of the greatest importance to consider how the pressure is applied to the material rolled. When the pressure is vertical, or nearly so, to the surface being rolled, it may be referred to as "direct pressure," and it is obvious that under such conditions the power required will be a minimum. When finishing material such as flanged rail or channel, where the pressure is almost

* Abstract of a paper read before the American Institute of Electrical Engineers.

parallel to the surface being rolled, the pressure may be very large for a very small amount of work done. This condition may be referred to as "indirect pressure."

The pressure on the rolls due to the metal introduces additional friction, but as this cannot be separated from the power actually required to displace the metal, it must be included in the specific power consumption. Also, there often is considerable friction between the rolls and the metal, due to the peripheral speeds of various parts of the section

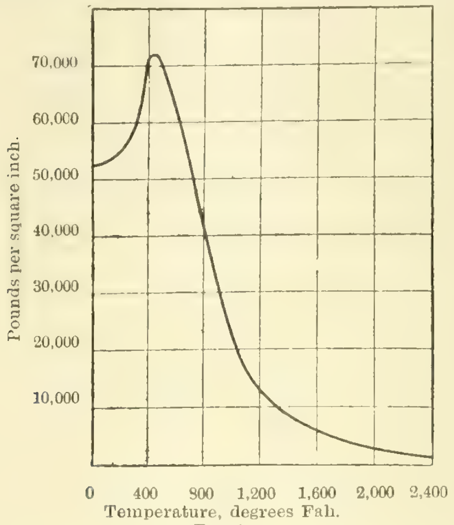


FIG. 1.

being different; this between the metal and the roll. In cases where a rail flange, for instance, is being finished, there is a tendency to move the rolls laterally in relation to one another, which may be taken up by indirect pressure in the opposite direction or in roll collars, in which case the friction is, of course, increased. It must, therefore, be included as part of the net rolling work, which is the actual input to the mill less the no-load friction.

Temperature of Metal.—This plays a very important part in the power required for any mill. Tests made indicate that the power requirements, all other things being equal, vary practically as the tensile strength of the material. There is not a great deal of information available as to the tensile strength of steel at various temperatures. Fig. 1 is a curve of tensile strength of mild steel at various temperatures, made up from information that has been published of tests in the Watertown Arsenal and from various European publications, as well as from tests made by the writer. The curve varies somewhat from others that have been published as to the strength at high temperatures, as the tests made by the writer indicate that previous estimates as to the tensile strength have been too low, and that instead of the curve gradually tapering to zero at the melting point, there is a point somewhere between 1,300° Fah. and 1,400° Fah. where the tensile strength rapidly decreases. Tests made at various temperatures when rolling plates, using only direct pressure, so that there are no other disturbing factors, indicate that this curve is approximately correct as indicating the relation between the power required to displace the metal and the temperature. The rate at which metal cools is obviously of the greatest importance, and within the usual limits of rolling temperatures it may be said that the rate of cooling will be practically proportional to the area exposed in relation to the volume. From Fig. 1 it will thus be seen that the power required to displace the metal will increase very rapidly as the cross-section is decreased.

Class of Material.—Tests made by the writer and others indicate that, provided the temperature is the same, the power required to displace a given volume of metal is practically independent of the chemical composition of the steel. This applies only within the usual rolling temperatures (1,800° Fah. to 2,400° Fah.). The density of the steel has considerable influence upon the power requirements, and when rolling ingots, the first one or two passes made require comparatively little power per cubic inch displaced, as the steel is more or less porous. After the metal has had one or two passes through the rolls, the density when hot apparently does not enter further into the question. When rolling steel cold, however, there is a continual increase of the power required due to the increased density, and in Fig. 2 is shown a typical curve indicating the increase in power requirements as the cross-sectional area is decreased.

Rate of Displacement.—Although little information is available, there are indications that the rate of displacement somewhat affects the power requirements. Tests made by the writer appear to show that a low rate of displacement requires less power than if metal is rolled quickly. In practice, however, metal is rolled as quickly as it can be handled, so that this feature is of comparatively little importance.

Size of Rolls.—Theoretical investigations show that when rolling plates or blooms or such sections where direct pressure only is used, the size of roll has some effect upon power requirements. Small rolls should require somewhat less power than large rolls, but the writer has not been able to demonstrate the accuracy of these theoretical calculations owing to the great many other factors which influence the test results.

Practical Determination of Motor Size.—The great majority of rolling mills are of the type running continuously in one direction, and to equalise the input to the motor flywheels are used. It is of the greatest importance to determine the size of flywheel required in conjunction with the characteristics of the motor and control apparatus, as it is only by considering them as a unit that a satisfactory installation can be made. With the ideal flywheel, a motor sufficiently large to carry the average load would be the right size to use, as all the peaks would be taken by the flywheel, and during the intervals between passes energy would be stored in it. In practice it is not possible to use such flywheels, as they would be excessively large, and consequently a compromise must be made between motor and flywheel. It is usual to consider that the mill will run for short periods at its maximum capacity, that is, with the minimum interval necessary to handle the material, and on this basis the load diagram must be determined. The load diagram can be determined from curves showing the power requirements per cubic inch displaced, in conjunction with the volumes displaced and the rate of rolling. From this diagram, the average load when the mill is rolling at the maximum rate can be determined, and also the size of the flywheel. The average production of the mill must be taken into consideration in determining the size of motor, so as to have an equipment which has suitable characteristics for the normal operating conditions.

In practice it has been found that, although the power required for the individual passes may vary quite appreciably from that calculated, the flywheel will have sufficient capacity to compensate for these individual variations, and that the general operating conditions of the motor can be fairly accurately determined. In practice it is advisable not to allow for an overload of more than 25 per cent. when rolling at the maximum possible rate, so that there is always a certain reserve available in the motor for extraordinary conditions that may arise. Rolling-mill motors are usually

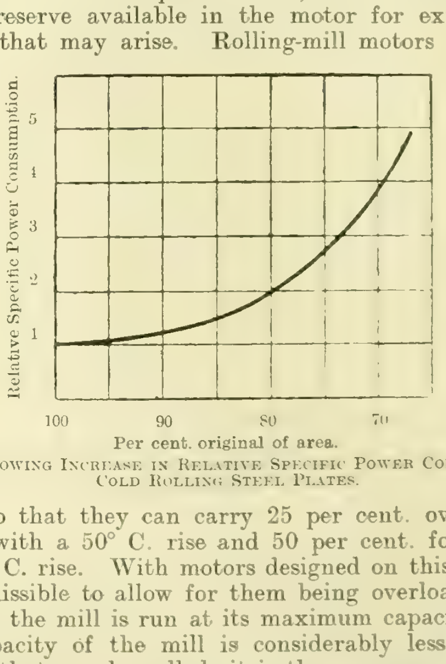


FIG. 2. SHOWING INCREASE IN RELATIVE SPECIFIC POWER CONSUMPTION COLD ROLLING STEEL PLATES.

designed so that they can carry 25 per cent. overload continuously with a 50° C. rise and 50 per cent. for one hour with a 60° C. rise. With motors designed on this basis, it is quite permissible to allow for them being overloaded 25 per cent. when the mill is run at its maximum capacity. If the hourly capacity of the mill is considerably less than the maximum that can be rolled, it is then necessary to investigate very closely the conditions existing, so as to determine on what basis the compromise must be made.

INDICATORS.*

BY JAMES G. STEWART.

THE indicator when used with the greatest care is, like many other instruments, subject to systematic errors, the presence of all of which has not yet been fully recognised. This paper describes some experiments which have been made to determine these errors; it discusses the defects of indicators, and, in order to give a concrete conception of the errors both in mean pressure and in the shape of the diagram, it gives the correction of the diagrams of Prof. Burstall's Crosby-Hopkinson comparison tests, a paper on which was read before the Institution of Mechanical Engineers in 1909. These have been chosen because there was there general agreement that the indicating was of the highest order possible with the given instruments.

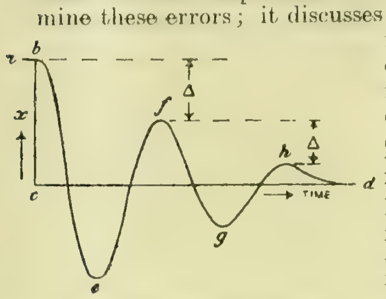


FIG. 1.—OSCILLATION CURVE.

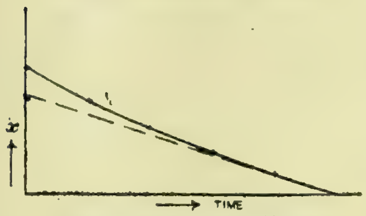


FIG. 2.—CURVE DRAWN THROUGH POINTS OF MAXIMUM AMPLITUDE.

The research has been carried out in the laboratories of the Mechanical Engineering Department of the University of Birmingham. The author wishes to acknowledge his indebtedness to Prof. F. W. Burstall for permission to use the indicators and for facilities to prosecute his research; he is indebted to Mr. A. W. Hone for his assistance in those parts of the experiments which could not conveniently be done by one experimenter.

A consideration of the uses to which some of the most eminent engineers have put the indicator and of the far-reaching deductions made by them led to this investigation of its behaviour. As it will give a clearer conception of the problem some of these uses will be briefly stated. Profs. Callendar and Nicolson,† in their classic experiments on the temperatures in the steam engine, found a discrepancy between the temperature of the steam as measured directly and as calculated from the indicator diagram. The discrepancy, although small, they explained by a theory of instability of state of steam during expansion; it could be explained very satisfactorily by an error in their indicated pressures if such could be proved to exist. Prof. Burstall in his gas engine work has made much use of the indicator; he has calculated from its diagrams the temperatures of the gases throughout the expansion stroke and compared them with actual measurements of these temperatures.‡ He has enunciated a law of cooling in the gas-engine cylinder, and supported it by the agreement of deductions made from it with the indicated form of the expansion line.§ Mr. Dugald Clerk, in his well-known work on the specific heat of gases, has depended almost entirely on his indicator diagrams.||

Prof. Bertram Hopkinson has also used his indicator to determine the specific heats of gases, and has found unexplained peculiarities towards the end of compression and beginning of expansion. The problem of the behaviour of gases in a gas-engine cylinder would be much simplified if these could be explained by errors in the indicator.

In steam engine work an almost absolute reliance is placed on the indicator diagram; from it one deduces dryness fractions of the expanding steam and draws the corresponding entropy diagrams; from which in turn various deductions are made of heat interchanges taking place in the cylinder. In the measurement of indicated horse-power there is not more reason for putting trust in the indicator. If through any cause a large amount of friction were offered to the motion of the pencil, the indicated horse-power would be much in excess of the true horse-power for diagrams of the usual shape.

The author's experiments lead to the conclusion that the errors in indicator diagrams are much greater than has been usually assumed. They show that there is a lag, often very great, of the pencil behind its true position, and that the error so introduced is not a constant but generally increases with the stiffness of the spring and with the pressure. Of equal importance is it that these errors, large, yet not readily apparent, are not uniform, but vary with different indicators and even with different springs of the same scale. These errors and the uncertainty of their magnitude are hurtful to the progress of engineering. The indicator should either be made an accurate instrument, or a ready means of measuring its errors should be devised. The methods used in these experiments go some way towards making the latter alternative possible, and the results, in so far as they point out the causes of errors, will be useful to designers in their search after the former.

Very few investigations into the behaviour of the indicator have been made. In 1885 Prof. Reynolds read a paper on the indicator, in which he discussed its errors.* He gave an equation of motion of the pencil which, however, neglected the presence of any damping forces; the equation unfortunately is not applicable to the correction of the ordinary indicator diagram. Reynolds gave a method of determining the friction by the use of a light spring. It has generally been accepted that the friction so determined is the friction resisting motion of the pencil, whatever be the spring used and whatever be the pressure on the piston; the friction in use is really much greater. Reynolds's theory of errors of drum motion is satisfactory so far as it goes, but a fuller treatment is advisable for present-day needs. Reynolds's paper was accompanied by one† by Dr. Brightmore, in which he gave the results of experiments which he had made. They went to show the presence of the factors discussed by Reynolds, but they did not, quantitatively, except in the case of the periodic time of an oscillation of the pencil, support Reynolds's theories.

Dr. Meyer, of Berlin, has discussed an equation of motion of the pencil, which differs from Reynolds's in that he introduces a term to represent the damping forces. These he assumes to be due to fluid resistances and proportional to the velocity of motion of the piston. The author's experiments do not support these assumptions. Such equations of motion, if they could be accurately applied, would be of value in cases in which changes of pressure are so rapid that the inertia of the moving parts is a predominating factor, for example, in the case of the correction of the diagram of an explosion in a gas-engine cylinder.

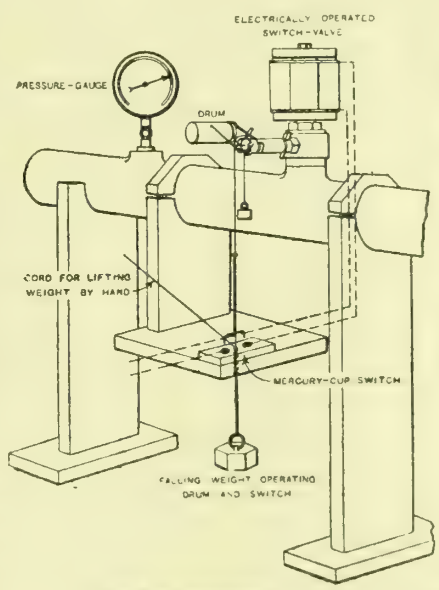


FIG. 3.—APPARATUS.

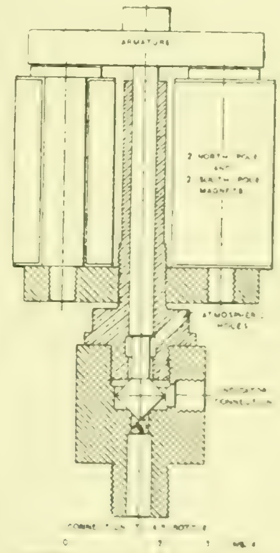


FIG. 4.—DOUBLE-SEATED VALVE.

There is in the indicator the possibility of two distinct errors:—

(1) The indicated pressure may not be that corresponding to the pressure in the cylinder, due either to friction or to inertia of the moving parts or to both.

(2) The position of the drum may not be that corresponding to the position of the piston, due to stretch of the string

* Paper read before the Institution of Mechanical Engineers, January 17th, 1913.
† Proceedings, Inst. C.E., 1897-8, Vol. CXXXI., page 147.
‡ Proceedings, Inst. Mech.E., 1901, Part 5, page 1031.
§ Proceedings, Inst. Mech.E., 1908. Third Report on Gas-Engine Research, Appendix I., page 18.
|| "Limits of Thermal Efficiency." Proceedings, Inst. C.E., 1906-7, and later Papers.

* Proceedings, Inst. C.E., 1885, Vol. LXXXIII., page 1.
† Proceedings, Inst. C.E., 1885, Vol. LXXXIII., page 20.

or to straining in other parts of the indicator gear. These will be considered separately.

In the author's experiments Crosby gas engine indicators, internal spring type, fitted with heavy pattern pencil gear, were used. As the only essential difference between the Crosby gas-engine indicator and the Crosby steam-engine indicator is the diameter of the piston, the results are applicable to the steam indicator, bearing in mind that the scale of the springs must be altered in proportion. Some experiments were also made on a Hopkinson optical indicator; this indicator was purchased by the Engineering Department of the University of Birmingham from the makers, Messrs.

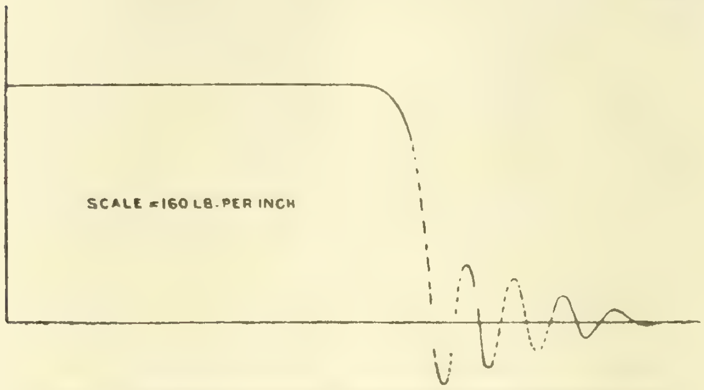


FIG. 5.—FACSIMILE OF ORIGINAL OSCILLATION DIAGRAM OBTAINED FROM APPARATUS FIG. 3 (full size).

Dobbie & McInnes, Ltd. One of the Crosby indicators was the special indicator used by Prof. Burstall in his gas engine research work (Crosby No. 1); the other and the one on which most of the experiments were made was chosen from the remaining indicators in the possession of the Department (Crosby No. 2).

As indicator diagrams are subject to error from many causes which are really defects of the engine and not of the indicator, it is necessary, in order to determine the errors of the indicator, to eliminate errors of the former class. In the pencil motion a chief source of error in steam-engine work is the presence of water in the indicator or in its connection with the cylinder; this has been avoided by using compressed air

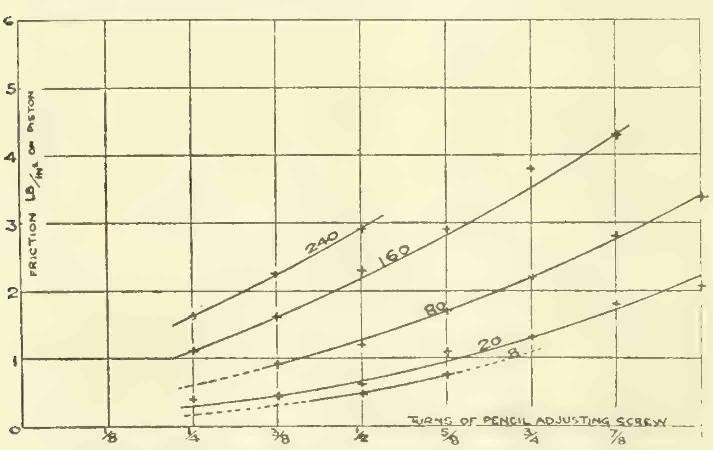


FIG. 6.—VARIATION OF FRICTIONAL DAMPING FORCES WITH VARIATION OF (1) PENCIL PRESSURE, (2) SCALE OF SPRING.

as a working fluid. In the drum motion errors of design of the indicator gear were eliminated by a differential method. Further, as no satisfactory deductions on pencil motion could be made from a diagram taken from an engine, a special method has been used.

Motion of the Pencil (or of the Equivalent Pressure-indicating Mechanism of the Optical Indicator).—To record the pressure accurately the pencil must have for each pressure a single definite position, and it must take this position whenever the pressure in the cylinder is that corresponding to the position. This is only approximated to in any indicator. Friction and the inertia of the moving parts introduce errors; there may also be an error due to slackness in the pins of the pencil gear, which error, however, is one which ought to be avoided. A knowledge of the friction and the inertia gives the data necessary to calculate the error in the motion of the pencil.

Frictional Resistance to the Motion of the Pencil.—If a Crosby indicator be subjected to pressures represented by the line *abcd*, Fig. 1, it will be unable to follow the instantaneous change of pressure represented by *bc*, and in consequence oscillations will be set up, and the pencil will give some such indication as *abefghd*, Fig. 1. These oscillations will gradually die out, and experiment shows that the damping per oscillation ($\triangle$) for each of the oscillations is very nearly constant, Fig. 1. It is slightly greater when the oscillations are large, but for general purposes this variation may be neglected. This condition of constant damping per oscillation is an indication of the nature of the friction which is

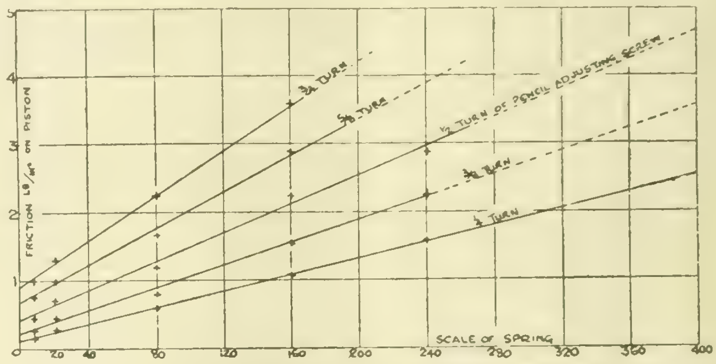


FIG. 7. VARIATION OF FRICTIONAL DAMPING FORCE WITH SCALE OF SPRING AND PENCIL PRESSURE.

damping the motion, namely, that it is "solid" friction, that is, it is of constant amount and always opposed to the motion; further, the frictional force is equivalent to $\frac{\triangle}{4}$ lb./in.² on the piston (*see* Appendix I.). As the successive maximum heights of the pencil above its true position can be measured and plotted, $\triangle$ can be obtained with considerable accuracy from the slope of the mean curve, Fig. 2. The slope at the point at which the curve cuts the time axis gives the true solid friction. Increased slope at other points indicates the addition of a small amount of fluid damping, Fig. 2.

Experiments to Determine Frictional Resistance to Motion of Pencil.—In these the apparatus shown in Fig. 3 was used. An ordinary high-pressure air-bottle had two bosses welded

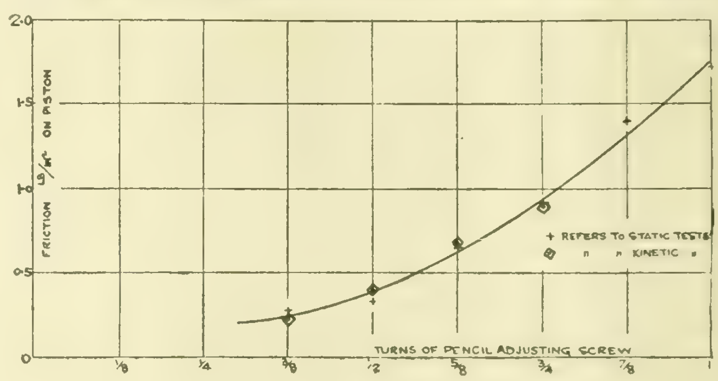


FIG. 8.

on; one carried a pressure gauge, the other a valve of special construction. The indicator was attached to the special valve as shown. The valve, which is shown separately in Fig. 4, was double seated. When the valve was on the lower seat the indicator was open to the atmosphere; when it was on the upper seat the indicator was open to the bottle, which in working conditions held air under pressure. This valve was operated by a magnet which made possible a very rapid switching over of the valve, and therefore subjected the indicator to a very rapid change of pressure. This sudden change is an approximation to the instantaneous change represented by the line *bc* in Fig. 1. The drum was actuated by a falling weight; the weight in falling pulled in the fork of a mercury-cup switch, thus closing the magnet circuit and switching the indicator from the pressure air to the atmosphere. By suitably timing this switch the valve could be made to act at a suitable time, and a record of the movement of the pencil was obtained on the diagram. The pressure of the pencil on the paper was adjusted by the screw provided, and the screw was held against the stop by hanging a small weight to it. Fig. 5

is a facsimile of an actual diagram obtained from this apparatus. It was originally intended that the switch valve should give a practically instantaneous change of pressure in the indicator cylinder. This, however, was found impossible, but fortunately the very satisfactory oscillation diagrams obtained were sufficient in themselves to give complete information.

The frictional damping forces were calculated in terms of their equivalent pressures on the piston of the indicator; they were found to vary with change of conditions. So far pencil pressure is the only recognised variable, but other and

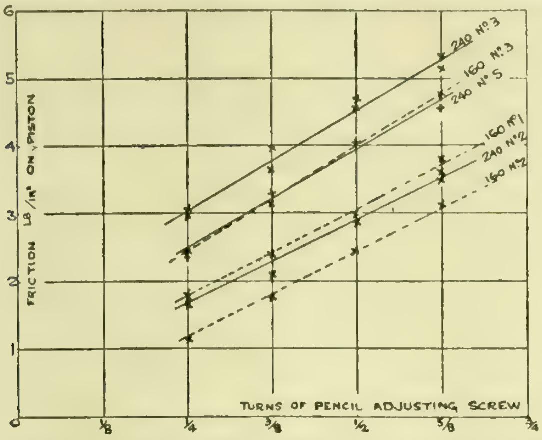


FIG. 9.—VARIATION OF FRICTION WITH DIFFERENT SPRINGS OF THE SAME SIZE.

much more serious causes of variation were found. It was only after much work that these variables were separated. Variation of the friction may be stated to be due to variation in:—

(1) The pressure of the pencil on the paper.
(2) The stiffness of the spring.
(3) Different springs of equal stiffness.
(4) The pressure of the working fluid in the indicator cylinder.
(5) Different indicators.

Of these (1), (2), and (3) were investigated on Crosby Indicator No. 2.

Fig. 6 shows the result of variation of pencil pressure and of scale of spring. As the pencil pressure was not directly measurable, it is given in terms of the turns of the pencil adjusting screw; the zero position is that at which the pencil is just touching the drum, no paper being on the drum. Fig. 7, which is deduced from Fig. 6, gives these results in a more useful form. The ordinates corresponding to the points at which the curves of Fig. 7 cut the vertical axis are plotted in Fig. 8, and for comparison the friction, as measured statically with a light spring in Reynolds's manner, is also

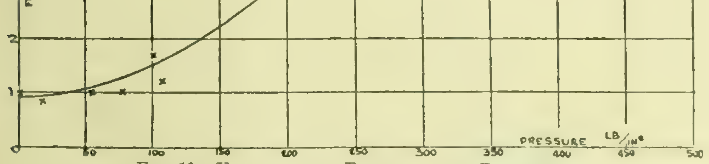


FIG. 10.—VARIATION OF FRICTION WITH PRESSURE.

No. 1, Crosby Indicator. Scale of spring=400. Pencil pressure corresponding to 3/8 turn of pencil adjusting screw.

plotted. It is noticeable that the two are in close agreement. Having established this relation, Fig. 7 shows the great excess of the friction over that obtained by Reynolds's method.

The curves given in Fig. 6 for the 240 and 160 springs are average curves. With these heavy springs much variation in the results was found when different springs were used (*see* Fig. 9, which has the same co-ordinates as Fig. 6). This shows the presence of the third variable.

The fourth variable which influences the friction is the pressure of the working fluid in the indicator cylinder. This variable was investigated for one case only, namely, Crosby Indicator No. 1, fitted with its 100 spring. This indicator and spring are those which were used in Prof. Burstall's Crosby-Hopkinson comparison tests. The results therefore are directly applicable to the correction of his Crosby diagrams. The results are shown in Fig. 10.

The pencil pressure throughout was constant and was that corresponding to 3/8 of a turn of the pencil adjusting screw.

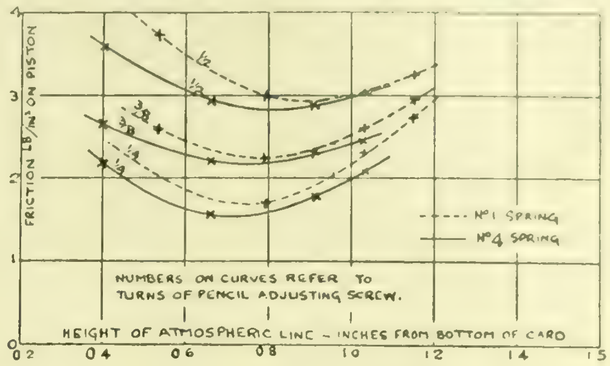


FIG. 11.—VARIATION OF FRICTION WITH HEIGHT OF PENCIL.

This is a very small pressure and one at which the friction of the pencil on the paper is so small that it may be neglected. It is about the pressure which one would adopt when carefully indicating an engine. The method of obtaining the results of Fig. 10 was different from that used in the other experiments. In these the indicator was in continual direct connection with the air-bottle. The height of the pencil above the atmospheric line was therefore that corresponding to the pressure of the air in the bottle. The pencil gear was tripped by pulling the piston rod up and then suddenly releasing it. This was done very simply by using the box-key supplied with the Crosby indicator. The box-key was held in one hand and with it the pin in the piston rod fork was caught; pulling, the pencil was deflected. The key was then allowed to slip off the pin and oscillations of the pencil resulted. The pressure in the indicator cylinder during the oscillation was that of the air in the bottle, and thus a means of measuring the friction at that pressure was obtained. There is the possibility in this method of the pencil pressure being interfered with, but there was nothing to show interference. Had it occurred it would have shown itself in the varying blackness of the pencil line. Moreover, if it had been present in sufficient amount to affect the results it could not have varied systematically throughout, and so could not explain the variation found. The author

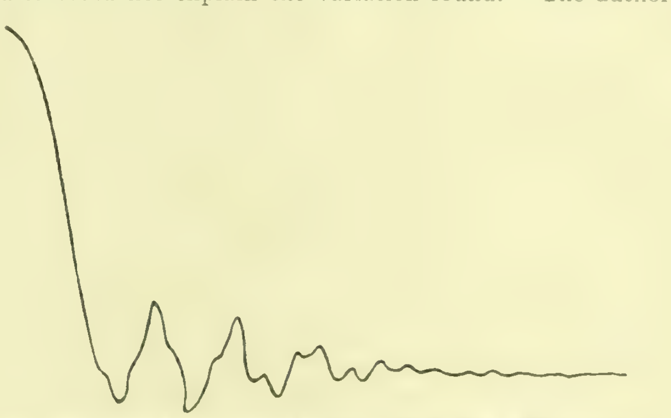


FIG. 12.—FACSIMILE FULL-SIZE OF ORIGINAL OSCILLATION DIAGRAM FROM HOPKINSON OPTICAL INDICATOR. Scale 20lbs per inch.

believes the results to be quite as accurate as those obtained by the other method.

The variation found appears to be a function not only of the pressure, but also of the position of the pencil. Some experiments which were made on two 240 springs show this. Oscillations were made in the usual way with the apparatus of Fig. 3. The pressure inside the indicator cylinder was atmospheric throughout the period of oscillation; the position

of the pencil was varied by means of the screw in the piston rod. The results of Fig. 11 were obtained.

In these as in all experiments with Crosby indicators the pencil used was of 5 H Koh-i-noor pencil lead. The paper was a writing paper with a smooth surface. The surface of the paper had a tendency to be glossy, in which state with small pencil pressures it did not readily show a pencil line. As it was important that the behaviour of the indicator, when strained as little as possible, should be known, dried paper was used. In the dried state the paper had a smooth matt surface which was easily marked by the pencil.

Friction in the Pressure-indicating Mechanism of the Hopkinson Indicator.—A few oscillation diagrams were taken with the Hopkinson indicator, using the apparatus of Fig. 3, but it was not possible to estimate from them the frictional resistance to motion, as the oscillation was not a simple one. Fig. 12 shows a facsimile one of these diagrams. It will be noticed that there is superimposed on the main oscillation a secondary oscillation and that the secondary oscillation is not a harmonic of the main one.

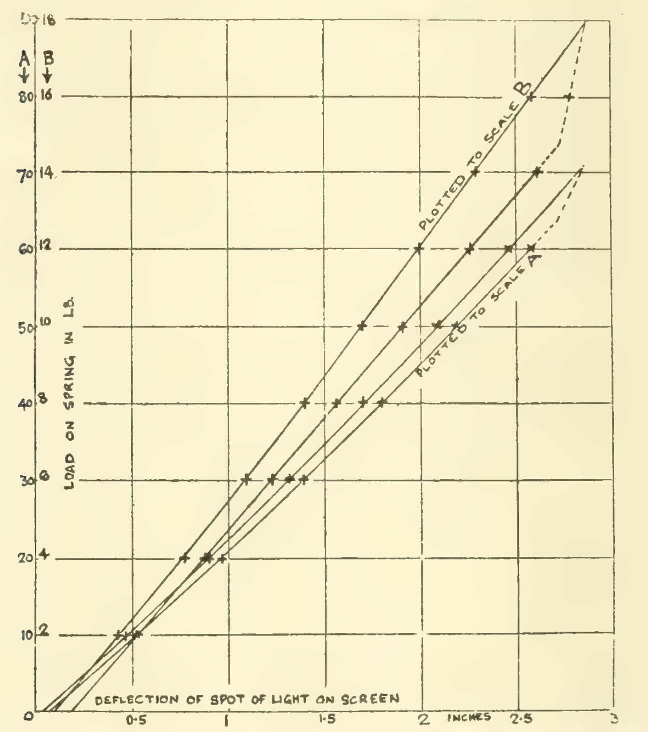


FIG. 13.—DIAGRAM SHOWING EFFECT OF FRICTION ON SPRING SUPPORTS OF HOPKINSON INDICATOR.

The static tests on this indicator were more valuable. The first test was intended to show the presence of hysteresis if such were present. To effect this the indicator was secured with its axis in a vertical position and with the spring on the under side of the cylinder. The spring was then loaded by hanging weights to the end of a stiff wire, the upper end of which was hooked to the spring. No piston was used, so that the only possible friction affecting the motion was that of the pivots of the mirror spindle or that of the spring in its supports. This latter, however, was believed to be negligibly small. Care was taken to load and unload the spring without jar. Plotting the results a diagram with a very large loop was obtained showing an error much in excess of what was to be expected from hysteresis. The only satisfactory explanation was that the friction of the spring in its supports, instead of being negligible, was really very large. If it were friction it could be eliminated by tapping. This was found to be the case, the spot taking a single definite position when thus relieved of friction. The tapping had to be vigorous and the final position of the spot of light was different with vertical and with horizontal tapping. In the early experiments the load had not been applied quite centrally, thus introducing a couple which may have caused the error to appear greater than should really have been the case. To eliminate this possibility, a wire was bent which would apply the load centrally. This gave the looped diagrams of Fig. 13.

(To be continued.)

THE RESISTANCE OF METALS TO ALTERNATING STRESSES.*

BY DR. T. E. STANTON.

THE investigations which have been in progress at the National Physical Laboratory from 1904 up to the present time on the resistance of metals to alternating stresses may be divided into two classes, according as the resistance is that due to: (1) Stresses alternating in a continuous cycle in which there is no instantaneous change in the value of the force on the specimen, although the period of one complete cycle may be as small as 0·02 secs. (2) Stresses alternating between definite limits, usually tension and compression stresses of the same value, which are produced by a shock repeated at equal intervals of time.

Class I.—The first machine of this class which was constructed at the Laboratory was one in which alternations of direct tension and compression could be produced in the specimen at rates varying from 800 to 1,300 per minute. The principle of this machine was that of Osborne Reynolds's, in which a rotating crank is used to produce periodic motion of a reciprocating mass by means of a connecting rod, the specimen under test forming a link between the reciprocating mass and the cross-head. In Reynolds's original machine only one crank was used, but in the machine at Teddington four cranks operating four specimens were employed, and the reciprocating motion took place in a horizontal plane.

A diagram of the mechanism is shown in Fig. 1, which also explains the method of balancing the cranks. The results of the investigations with this machine when making

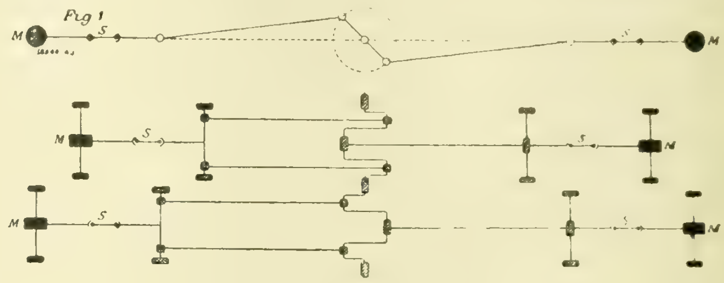


FIG. 1.

800 alternations per minute were in general agreement with those of Wöhler as far as the materials used could be compared, and at this speed there was no indication of the reduction in fatigue strength† due to rapidity of alternation which had been found by Reynolds and Smith when using a similar mechanism at speeds of 1,200 to 2,000 a minute. In these experiments at Teddington the manner of failure of the specimen under direct stress was shown to be similar to that found by Ewing and Humfrey in the case of bending stresses, *i.e.*, slip lines gradually appeared on the surface of the specimen, broadening out as the test proceeded, and finally developing into a crack. Further important results were the marked reduction in fatigue strength due to sudden changes in section, such as screw threads and sharp corners in the specimens.

The next investigation undertaken was that by Mr. L. Bairstow on the determination of the range of the elastic limits of iron and steel under cyclical variations of stress. In connection with this work, it may be recalled that Prof. Bauschinger in 1886 laid down the hypothesis that the range of stress between the superior and inferior elastic limits in iron and steel is the same in magnitude as the maximum range of stress which can be repeated without limit in a specimen of the same material without causing fracture. In a second paper in 1897 a series of tests made by Bauschinger with the object of experimentally verifying the hypothesis is discussed, but the experimental methods do not appear to have been sufficiently refined for the purpose of the determination, and the results were indefinite. In taking up the investigation Mr. Bairstow made use of a testing machine in which cyclical variations of direct stress were automatically produced at the rate of two per minute, in such a manner that the extensometer used, which was of

* Paper read before the International Association for Testing Materials.

† The term "fatigue strength" is used in this paper to denote the maximum range of stress which a material will endure without fracture when the number of repetitions of the stress is unlimited.

the Martens mirror type, was fixed to the specimen throughout the whole of the fatigue test, and in this way the complete phenomena of the breakdown could be observed.

When the limits of stress were tension and compression of equal values it was found that, when the range of stress was above a definite value, the stress deformation curve formed a closed loop which was called the hysteresis loop, consisting of two parallel straight lines corresponding to the variation of stress from the limits of stress towards the mean stress and two curved portions corresponding to variations of stress from the mean value to the extreme values. The width of this loop, which was the permanent "set" of the specimen per cycle, increased as the range of stress increased, but for a definite range of stress tended to a limit which was not greatly exceeded by subsequent repetitions of loading, even when this was the range at which fracture under fatigue eventually took place. Under these conditions of stress the mean length of the specimen remained constant.

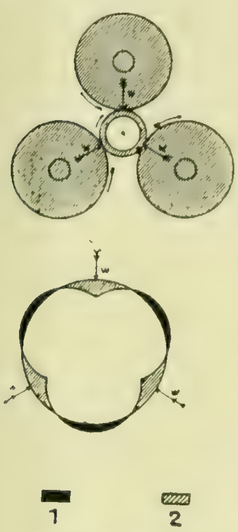


FIG. 2. DISTRIBUTION OF STRESS AT OUTER SURFACE OF RING. 1 Tension; 2—Compression.

When the limits of stress were unequal the hysteresis loop was formed as before, but was not closed, owing to the fact that the mean length of the specimen gradually changed owing to the continued repetition of the same cycle of stress, *i.e.*, the change of mean length of the specimen per cycle was the amount by which the hysteresis loop was unclosed. The amount of the permanent extension during the earlier stages of the breakdown becomes considerable as the superior limit of stress approaches the static yield point, and if its value after the first considerable stretch has occurred be plotted against the corresponding values of the superior limit, it will be found that the curves will gradually come into coincidence with the ordinary static "force-elongation" diagram at the yield point. The results of the research formed a very definite experimental confirmation of Bauschinger's hypothesis.

During the last two years another investigation has been in progress to determine the effect of rapidity of alternations on the fatigue strength of material. For this purpose a special machine of the Wöhler type has been constructed, and by the additional device of a dashpot to damp out oscillations, provision has been made for obtaining a range of speed from 200 to 2,200 per minute. A long series of tests at speeds of 200 and 2,200 cycles per minute have been carried out on three kinds of material, Swedish iron, axle steel, and hard spindle steel. The results of these tests have shown conclusively that in no case is there any difference in fatigue strength due to a variation in the rapidity of alternations between these limits.

Another method of high-speed fatigue testing, in which the specimen is in the form of a hollow ring of rectangular section, has also been developed as a check upon the foregoing results. The specimen R (Fig. 2) is placed between three hardened steel rollers symmetrically situated as shown. The upper roller is loaded with a weight W, so that the ring is in equilibrium under three equal forces W at the lines of contact, and by rotating the upper roller motion is communicated to the lower ones by the rolling friction of the ring. In this way every radial section of the ring is subject to alternate bending stresses which go through a complete cycle three times in one revolution. In the machine constructed the diameter of the rollers was three times that of the specimen, so that by rotating the roller at 250 revs. per minute alternations of stress were produced in the specimen at a rate of 2,250 per minute. The superior and inferior limits of stress at the inner and outer surfaces of the ring can be calculated from the dimensions of the ring and the load. The distribution of stress at the outer surface is shown in Fig. 2.

The results of the experiments made with this machine were in agreement with those made on the Wöhler type machine referred to above, both as regards the magnitude of the limiting ranges of stress and the independence of the range on the rate of alternation. In view of recent confirmation of these results by Messrs. Eden, Rose, and Cunningham,* and of the results obtained by Prof. Hopkinson† at alternations of 7,000 per minute, there appear to be little doubt that the previously observed reduction of strength with rate of alternation is due to some secondary stresses set up by the vibration of the particular machine used.

Class II.—In a research on the methods of impact testing at the National Physical Laboratory in 1907, from considerations of the fact that failure under shock in practice is generally due to a comparatively small blow many times repeated, a machine was designed and constructed for the subjection of a specimen to alternating shock stresses of equal and opposite sign. The general arrangement of the machine is shown in Fig. 3. The specimen, which is 12·7 mm. diam. and has a V-notch at its half-span 10·4 mm. diam., is supported on knife edges 114 mm. apart, and struck alternately at each end of a diameter of the notched section by a hammer weighing 2·13 kilos. The fall of the hammer can be adjusted between 0 mm. and 89 mm.

In making a series of tests on any given material, the first tests were made with a height of fall which caused fracture after a few reversals. Succeeding tests were then made with gradually reduced falls until the specimen was not broken after 1,000,000 blows. A curve was then plotted and the limiting value of the blow for no fracture predicted from this. In this way four curves were determined for four different materials, of which the fatigue strengths under the Wöhler test were approximately known. On comparing the relative resistances to shock of these four materials, it was found that when the number of blows for fracture was small these relative resistances were in agreement with the respective energies absorbed in fracture with the single blow impact test. (Charpy, Izod, &c.) When, however, the number of blows was considerable, say 100,000, the ratios of these resistances was practically reversed, *i.e.*, the material which was weakest under the single-blow method now became

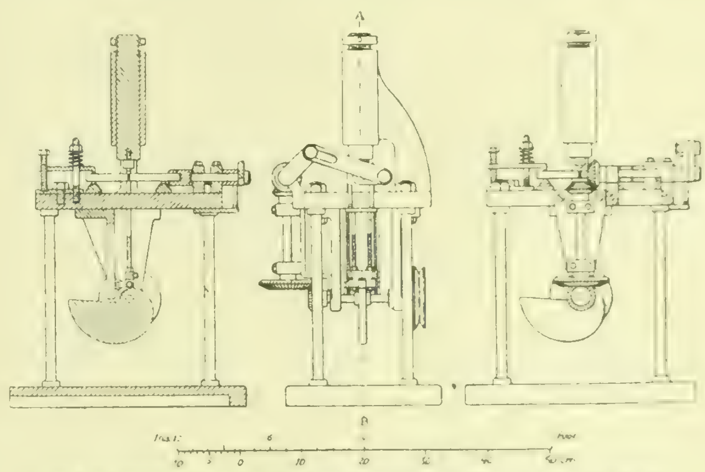


FIG. 3.—REPEATED-IMPACT TESTING MACHINE FOR BENDING OF NOTCHED SPECIMENS.

the strongest. This is due to the fact that as the number of blows for fracture increases, the elastic resistance, which was inappreciable in resisting a heavy blow, becomes more and more important.

Further, it was noted that if the respective values of the proof resilience for these four materials were calculated, *i.e.*, the values of $\frac{1}{2}\frac{f^2}{E}$ where f is the real elastic limit of the material derived from the Wöhler test and E is Young's modulus of elasticity for the material, then the ratios of these resiliences were approximately the same as the ratios of the respective limiting values of the blow for no fracture after an indefinite number of blows. The conclusion therefore arrived at was that, if the correct value of f could be obtained from the fatigue test of a material, then the value $\frac{f^2}{E}$ could be taken as a measure of its resistance to repeated shock stresses.

* Proc. Inst. Mechanical Engineers, 1911.
† Proc. Royal Society, Dec., 1911.

BEARDMORE'S TWO-STROKE CYCLE INTERNAL-COMBUSTION ENGINE.

WE illustrate herewith a design of 2-stroke cycle internal-combustion engine of the type having oppositely reciprocating pistons one within the other and coupled to opposite cranks, the outer piston being connected to an annular pump piston working in an annular pump barrel arranged on the outside of the inner end of the cylinder in which the two pistons work, the joint invention of Mr. William Beardmore, Parkhead Forge, Rolling Mills and Steel Works, Glasgow, and Mr. J. W. B. Stokes. Fig. 1 is a vertical section of the engine, and Fig. 2 a side elevation showing four such engine units so combined and arranged that they all act on a single 3-throw crank shaft.

The engine comprises a crank case through which passes a shaft A having a triple crank within the case, the central crank pin being at 180° to the two outer crank pins. The crank case carries an annular gas chamber B connected by a pipe to any suitable source of supply. The inner end of the cylinder is of larger internal diameter than the outer end and serves as a combined gas and air pump barrel C, whilst the outer narrower end D forms a liner in which works the outer or back piston E. This outer piston carries an inwardly extending sleeve F within which the inner or front piston G works. The sleeve F also acts as the inner wall of the pump barrel C, and carries at its inner end a pump piston H. This pump piston H and outer piston E connected together by the sleeve F are operated through connecting rods from the two outer cranks, whilst the front piston G is operated by a single connecting rod from the central crank. The pump piston H controls ports J giving communication between the gas chamber B and the pump barrel C, and ports K are formed through the part of the sleeve F of the outer piston E which is just in front of the pump piston H, the sleeve ports K being controlled by the inner piston G. In the position of the pistons shown in Fig. 1 the pump piston H is admitting gas to the pump barrel C. The sleeve ports K are also uncovered and admitting air to the barrel from the crank case, the air entering the case through an aperture or apertures formed through the sides thereof. The outer surface of the pump piston is shaped as shown with an annular lip, so that the gas and air flowing into the pump barrel from the oppositely disposed ports have little tendency to mix, the gas being directed upwards around the outer wall of the pump barrel C, whilst the air is admitted at the interior portion and so directed as to form an inner concentric layer. Exhaust ports L are formed through the sleeve F of the outer piston E, and the usual firing plug is so attached to the liner D in which the piston E works that the compressed charge has access to it through such ports. The outer end of the cylinder is closed by a cap and communicates through ports M with an exhaust chamber N. The cylinder and pistons may be water-jacketed, or the engine may be cooled by the injection of liquid into the cylinder.

When ignition of a charge takes place the outer and inner pistons E, G are forced apart as usual. The outward travel of the outer piston E and its sleeve F also the inward travel of the inner piston G closes the gas and air ports J, K, and causes the pump piston H to compress the charge previously admitted to the pump barrel C. When the two pistons E, G have reached the end of this stroke, the exhaust ports L in the sleeve of the outer piston E are opposite exhaust ports M in the cylinder liner D, and the products of combustion escape to the exhaust chamber N. At the same time the ports K in the sleeve F are open to the space between the two cylinder pistons E, G, and a scavenging charge of air first passes from the pump barrel C into the cylinder followed by a mixture of air and gas, becoming richer in gas towards the end. The cylinder pistons E, G then approach each other, compressing the charge just received and again placing the pump piston H in the position shown in which air and gas is admitted to the pump barrel C.

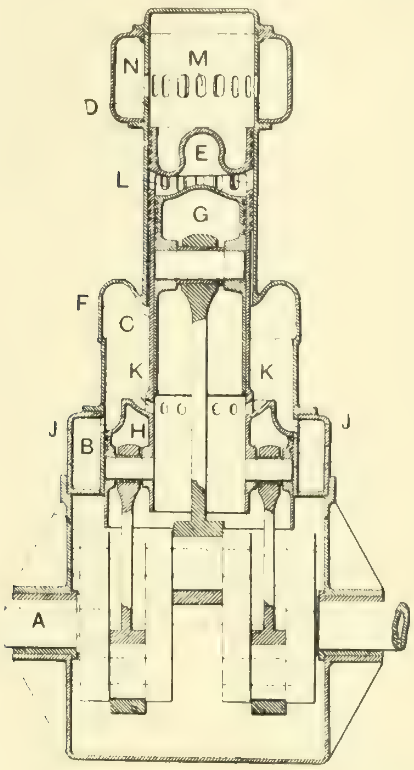


FIG. 1.

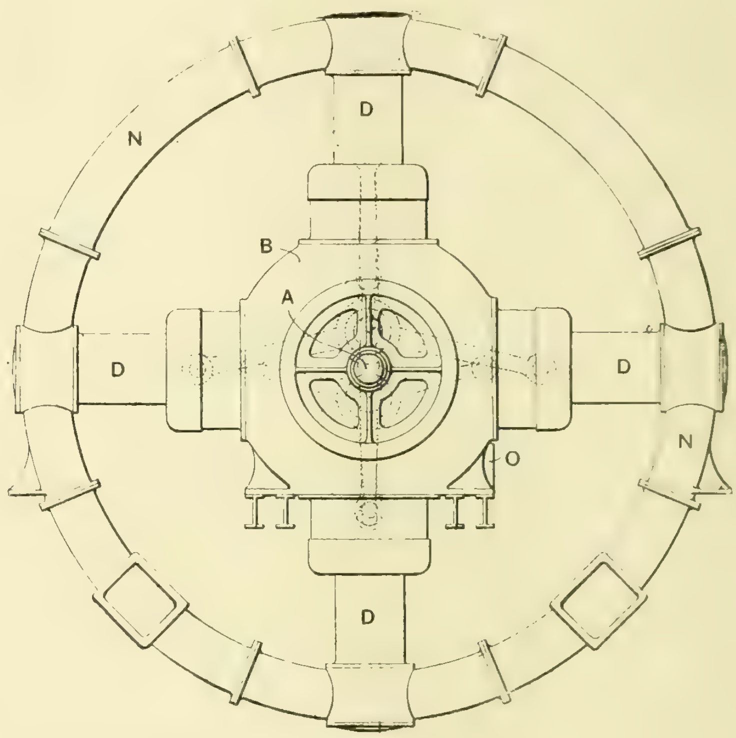


FIG. 2.

BEARDMORE'S TWO-STROKE CYCLE INTERNAL COMBUSTION ENGINE.

As shown in Fig. 2, four of the units described above are arranged in one plane symmetrically around a central crank case, so that they operate the single 3-throw crank shaft A, all the connecting rods from the inner pistons G being connected to the central crank pin, and the rods from the combined outer pistons E and pump pistons H of all the units being connected to the two outer cranks. The gas chamber B extends concentrically around the crank case, gas being led thereto by a pipe connected to an inlet O, and the exhaust ports in the outer ends of the cylinder liners D open into a common concentric exhaust pipe N. The engine is carried by brackets on the crank case supported by metal beams. The cycle of operations described for a single unit takes place, of course, successively in each of the units of the combination shown in Fig. 2. For example, with the 3-throw crank in the position shown and turning clockwise, ignition of the charge is just taking place in the upper unit. In the right-hand unit the charge is being compressed. In the lower unit the space between the piston cylinders E, G is open to the exhaust and also receiving a fresh charge, whilst in the left-hand unit the two pistons are being forced apart by the exploded charge.

STEAM TURBINES v. INTERNAL-COMBUSTION ENGINES.

THE Watt anniversary lecture under the auspices of the Greenock Philosophical Society was delivered on the 16th inst. by Mr. S. Z. de Ferranti, past president of the Institute of Electrical Engineers, and dealt with the subject of prime movers. After referring to the work of James Watt, Mr. Ferranti traced the development of the internal-combustion engine. Years ago, he said, an engine was invented and built by Lenoir in which a charge of air and gas was sucked into the cylinder at atmospheric pressure and exploded. The piston speed in this engine was low, the ratio of expansion was low, and the economy was very poor. Still, it was a step in the direction of higher economy, inasmuch as by this system a higher temperature of working fluid was obtainable. Later Otto and Langen invented a gas engine in which a flying piston was used, driven upwards by the explosion of a mixture of gas and air introduced into the cylinder without compression. The pressure of the atmosphere aided by the weight of the piston pressed the piston downwards, and, through an ingenious clutch and a rack and pinion, it gave rotary motion to the flywheel. The next move forward was that of compressing the charge of explosive mixture before firing, and so obtaining a high maximum temperature, a good ratio of expansion, and consequently much improved economy. Engines of this type belonged to a class of prime movers with "high negative work." In this form of engine the positive work of the explosion had to have deducted from it not only the friction of the engine, but also the amount of work required to compress the charge which constituted the negative work of the cycle. There was a further deduction—that of the friction of the engine or of a separate pump while doing negative work. These deductions would render this class of motor useless were it not for the high mechanical efficiency of the parts used for carrying out the cycle.

In the gas engine the negative work was high, but not so high as to form a serious difficulty. In the more economical Diesel engine, in which very high pressures were used so as to get a high enough temperature to burn the oil as sprayed into the cylinder and give a high ratio of expansion, the negative work was a much more serious difficulty—so serious, in fact, in the first Diesel engine that it required more power to overcome the friction and negative work than the engine was capable of giving, so that it would not even drive itself, much less was it capable of doing any useful work. The cycle of the engine was modified therefore in the direction of making it less perfect theoretically, and so enabling the engine to become the success which it now was.

The internal-combustion engine and the steam turbine were now competing for premier place in furnishing the world's power. The turbine, though less economical in actual fuel consumption, had many great advantages, and for large powers it was practically unassailable. For small powers it was naturally uneconomical. It seemed to be clear that for small powers the internal-combustion reciprocating engine was in every way the best. At the other end of the scale the turbine was the only means of filling requirements to-day. In between these two extremes there was a doubtful dividing line, where either form of engine might best serve the purpose, according to the conditions of each particular case.

As the turbine became larger so it was easier to construct, and it also became more economical. As the gas or oil engine became larger the natural difficulties increased. On the other hand, as the turbine was reduced in power its economy fell off badly, and it was difficult to make of a satisfactory design, while the internal-combustion engine became a most satisfactory and economical machine in small sizes. He thought that this division of the means of power production by large and small units between the rotary and reciprocating machine was almost a natural law, and that those who sought to evade it must either invent some new principle or court endless trouble, expense, and failure.

To-day, however, with a complete disregard of these principles the advocates of the Diesel engine for marine propulsion were spending vast sums of money on its development. Even this usually all-powerful force might not prove enough to make a wrong principle right. They were told of the wonderful successes of large oil engines in Germany and elsewhere, but few people had any conception of the failures and breakdowns which had occurred and which were occurring repeatedly with the large experimental engines which had been constructed. In Germany especially, where so much had been done in this direction, they carefully avoided informing the foreigner on these points.

It was well known, of course, that the higher the temperature of the working fluid the higher was the economy that could be obtained. High temperatures had proved, however, very difficult to work with. As an example of this, the low working temperatures of turbines for marine propulsion might be pointed out. Seeing that the difficulties were mechanical and that great advantages could be obtained if these troubles were overcome, he commenced experimenting some years ago, and had now, after many failures and the expenditure of much money and time, produced a turbine which, at the highest temperatures and with great and rapid variations of temperature, was quite free from mechanical troubles. Indeed, he believed that this turbine was perhaps the strongest from a mechanical point of view that had yet been produced. Moreover, contrary to what might have been expected with a high temperature machine, it ran with certainty with a blade end clearance so small that it was almost negligible from the point of view of leakage loss, and the fear of the possibility of stripping appeared to have been effectively removed.

In this turbine he superheated the steam initially, and after the first expansion and whilst it was still superheated he re-superheated it before it did its work in the second stage of the turbine. After this it was exhausted in a superheated condition through a regenerator to the condenser. Although the turbine was of the reaction type, no balance dummy was used. The whole of the end load was taken on a specially constructed thrust, thus saving steam leakage. The steam was worked as a gas at high temperature throughout the turbine, and this, coupled with the many improvements referred to, had given very good results. The 5,000 h.p. machine, which had now been running for some time, when tested at a load of two-thirds full power, had given a shaft horse-power on 7lbs. of steam. This, if supplied by an oil-fired boiler superheater system of 85 per cent. efficiency, which had already been exceeded in central station practice, would consume less than ·625lb. of oil per shaft horse-power. It appeared that when this turbine was run at full load under favourable conditions it would take less than 6lbs. of steam per shaft horse-power, and that the system, under the conditions named, would have a thermal efficiency of over 24 per cent., corresponding to an oil consumption of about ·55lb. of oil per shaft horse-power. So far as he could see, this system, when applied on a large scale, would be capable of giving an overall thermal efficiency of 29 per cent.

With a high temperature steam turbine of large size generating electricity for all purposes on land they had the advantage of a machine of the highest efficiency which was not limited to oil for its fuel. It was probable that as improvements were made the whole of the coal used for firing these large units would be gasified, and the by-products recovered. The great problem for this country was to so utilise the coal as to make it fill their every requirement. The electric motor which gave its power in a rotary form, and which was supplied from very large power stations, was displacing all forms of small engines. It was probable, therefore, that in future small prime movers would be required only to propel cars and boats, and that all stationary motors would be electric. Reciprocating engines would be used no doubt for a long time, but they could only be regarded as makeshifts, and as soon as an equally efficient machine for any particular purpose was developed it would displace the reciprocating motor. It was difficult to predict the form of the prime mover of the future, but in search of the highest economy, and with the limitations of temperature imposed by known materials, one was inclined to look to electricity, converting the energy of the fuel at low temperature and giving its power in rotary form, as the most likely eventual solution.

THE CUTTING AND GENERATION OF GEAR TEETH BY MODERN GEAR-CUTTING MACHINERY.*

BY VINCENT GARTSIDE.

(*Continued from page 60.*)

SPUR GEARS. CUTTING WITH DISC CUTTERS.

THE shape of the teeth cut by this method depends primarily on the accuracy and the profile of the cutter teeth It will not be out of place here to consider the types of cutters used, and how they are made. The oldest types of cutters are those with formed teeth, that is, with saw shaped teeth, which have been milled out of the solid, the blank first being turned on its periphery to a gauge set out by one of the methods previously described. The type of machine used for this method is shown in Fig. 11, the blank being mounted on a suitable mandrel, and the cutter guided by the handles over a former until a suitable margin is left along the cutting edge of the teeth. This type of cutter, however, has the great disadvantage that it cannot be sharpened easily without it changing its form, although it produces an excellent finish on the teeth, and cuts very freely. It is also limited in its use owing to the practical difficulty of producing the correct forms for pinion teeth because of the small diameter milling cutters which have to be used to produce the curves of small radii for these teeth.

The type of cutter in general use at the present time is the machine-relieved cutter brought out by Brown & Sharpe,

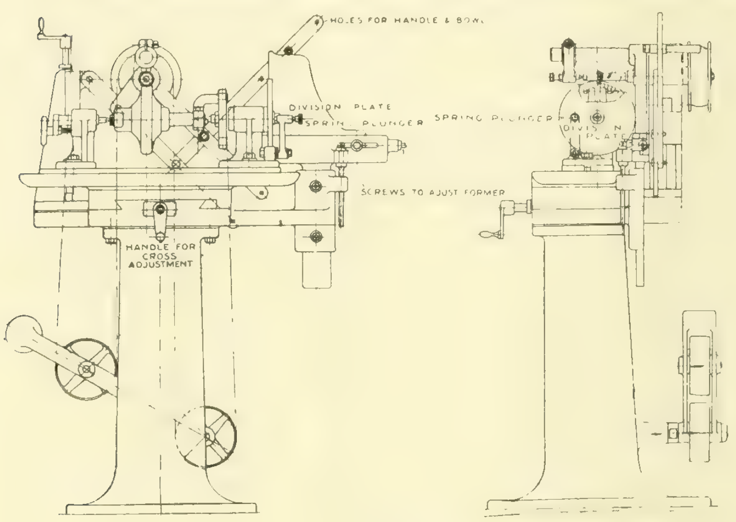


FIG. 11.

and the author's firm was one of the earliest to manufacture these cutters in this country. The author's first experience with the manufacture of these cutters was in the making of the gauges, and these were set out to the Willis odontograph for the cycloidal gears and to the single curve system for the involute. Then the Brown & Sharpe system was adopted, but with what was known as the Manchester depth, viz., three-tenths of the pitch above the pitch line, and four-tenths of the pitch below. By this time, however, the Brown and Sharpe depth was becoming recognised as the standard, and gear users began to call for cutters to cut gears of B. & S. shape, or, at least, to gear with this shape, so in order to keep abreast with the times it was decided to adopt Grant's method and to use the Grant odontograph and to keep to the B. & S. standards for depths; since then this has been the author's practice for both involute and cycloidal teeth.

In making the cutters the gauge is first accurately laid out on blackened zinc, a "he" and "she" being filed out and tested for reversing in each other accurately, a gauge being made to the micrometer to gauge the width at the pitch line. A master tool is then turned up to this gauge, this being an extremely accurate piece of work, and generally performed by a very skilled turner: the tool is then cut away by milling, as Fig. 12, and afterwards hardened and ground on the face, and mounted up on a slotting machine, as Fig. 13, and a flat tool slotted out with this master tool, as shown. This tool is then hardened and touched up with an oil stone, and sharpened on the face. This then is the master tool for turning and relieving the cutter; the most important point, however, in the manufacture of this type of

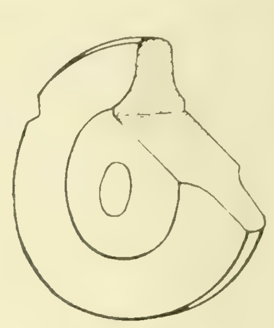


FIG. 12

FIG. 13

cutter is getting the tooth form correct in relation to the cutter body, so as to cut the teeth straight up on the wheel when the cutters are set central: in order to make sure of this you take a cast-iron blank and turn it up with the tool in the lathe, and reverse the blank and re-turn time after time, and adjust the tool until the turned form on the blank fits into the tool when turned round between the centres. This blank is then kept as a master and placed between the centres of the relieving lathe, to set the tool to for relieving the cutter. The angle for the relieving tool is about 20 per cent., so as to give enough clearance with a suitable relief on the cutter.

The amount of relief is governed by the number of teeth in the cutter. For very large cutters the author has made them in halves, giving each half side relief, and arranging spacing washers so as to be able to pack the cutters out to correct pitch line thickness, as they have become narrower by grinding. After the cutter is relieved it is, of course, hardened and ground in the hole and on the sides, and sharpened by grinding the tooth face, this face being kept perfectly radial. Owing to the method of relieving it retains its shape so long as the teeth last. As the tooth forms vary in shape, according to the number of teeth in the gear, different cutters have to be used for different numbers of teeth, and an ordinary set of involute cutters generally consists of eight cutters numbered from 1 to 8. A more accurate set

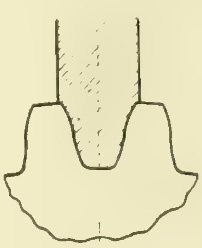


FIG. 14.

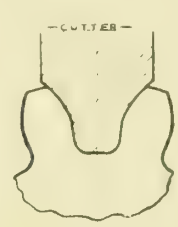


FIG. 15.

has been recently introduced, as below, to meet the more exacting requirements of the motor-car industry.

No. 1	will cut wheels from	135	teeth	to a rack.	
,, 1½	,, ,,	80	,,	134	teeth.
,, 2	,, ,,	55	,,	79	,,
,, 2½	,, ,,	42	,,	54	,,
,, 3	,, ,,	35	,,	41	,,
,, 3½	,, ,,	30	,,	34	,,
,, 4	,, ,,	26	,,	29	,,
,, 4½	,, ,,	23	,,	25	,,
,, 5	,, ,,	21	,,	22	,,
,, 5½	,, ,,	19	,,	20	,,
,, 6	,, ,,	17	,,	18	,,
,, 6½	,, ,,	15	,,	16	,,
,, 7	,, ,,	14	,,		
,, 7½	,, ,,	13	,,		
,, 8	,, ,,	12	,,		

For the epicycloidal system, owing to the peculiarity of this gear allowing of no adjustment, 24 cutters are considered

* Paper read before the Manchester Association of Engineers, January 11th, 1913.

as a set to cut gears as follows, the cutters being figured alphabetically.

Cutter A	cuts	.. 12 teeth.	Cutter M	cuts	27 to 29 teeth
,, B	,,	.. 13 ,,	.. N	..	30 to 33 ,,
,, C	,,	.. 14 ,,	.. O	,,	34 to 37 ,,
,, D	,,	.. 15 ,,	.. P	,,	38 to 42 ,,
,, E	..	.. 16 ,,	,, Q	..	43 to 49 ,,
,, F	..	.. 17 ,,	.. R	,,	50 to 59 ,,
,, G	,,	.. 18 ,,	.. S	,,	60 to 74 ,,
,, H	..	.. 19 ,,	.. T	..	75 to 99 ,,
,, I	,,	.. 20 ,,	.. U	..	100 to 149 ,,
,, J	,,	21 to 22 ,,	.. V	,,	150 to 249 ,,
,, K	,,	23 to 24 ..	.. W	,,	250 to Rack
,, L	,,	25 to 26 ,,	.. X	,,	Rack

These cutters were generally made with a shoulder, as Fig. 14, to denote the depth to be cut in the gear, as this was considered to be very important to ensure correct depths and centre distances. The involute cutters, however, were made to run out, as in Fig. 15. But to-day the shoulder on the epicycloidal cutters is not looked upon as a necessity, owing to the facilities for setting the cutters to the correct depth by means of micrometer dials, &c., and it will be obvious that it would be absolutely useless if the blank diameters were

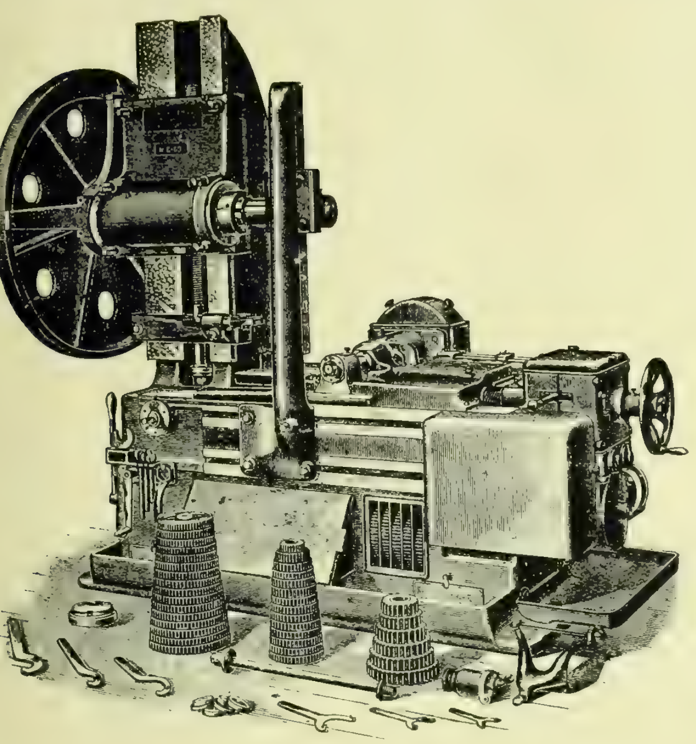


FIG. 16.

not correct, of course assuming that the outside diameter of the blank was used to measure forms.

Having selected a suitable cutter, the selection of the most suitable machine for the work depends on the pitch of the teeth and the diameter of the wheel which has to be cut. In laying out the gauges for the different sets of cutters, each gauge is set out for the lowest number of teeth in each range. If the number of teeth cut in a wheel is greater than the smallest number that the cutter is laid out for, the effect is to make the teeth thinner at the point, which, although not quite correct, will at least run without interference. It would be impossible to describe minutely all the various makes of machines for cutting wheels with disc cutters, but the following are typical examples of the different classes of machine in use at the present day.

The ordinary plain milling machine is sometimes arranged for cutting spur gears, a pair of dividing heads being mounted on the table of the machine. In some cases a dividing plate is mounted directly on the end of the mandrel, the plate very often having as many notches as teeth to be cut, and a suitable plunger to engage with the notches, the dividing being done by hand, the work being mounted between the centres, and a suitable driver or carrier being employed to connect the work mandrel to the spindle carrying the dividing plate. The feed is obtained by traversing the table by means of the screw, either automatically or by hand. The size of wheel cut on a machine of this description is governed by the swing of the dividing heads and the strength of the cutter drive. Where a number of different numbers of teeth have to be cut, then a worm-wheel dividing head is used, with dividing plates with a number of holes.

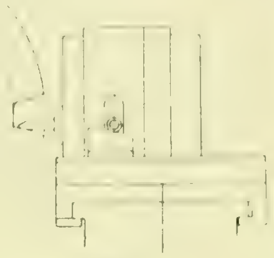


FIG. 17.

A special machine is arranged with automatic dividing mechanism to turn the dividing plate, and with a cam feed motion, the latter being a very simple method of obtaining a quick return to the work or cutter. A machine of this type is suitable for cutting small-pitch gears up to about 4in. diam. by about 2in wide.

Similar machines to Fig. 16 are made, but the dividing is automatic, and a worm and wheel is interposed between the dividing plate and the work, and by taking more or less teeth on the ratchet wheel different numbers of divisions are obtained, and the worm and wheel ensure great accuracy.

Fig. 16 shows the most general type of spur gear cutting machines. The dividing is done automatically, being actuated by tappets, by each stroke of the cutter slide. The work mandrel is arranged to raise and lower to suit the diameter of wheel being cut. Micrometers are provided for setting the depth of cut. A large dividing wheel is mounted on the end of the work mandrel with provision for taking up wear either by means for placing the worm further in gear or by means of a split worm, making the adjustment by moving one-half of the worm axially. The cutter is carried in a slide which traverses by means of a screw with quick return motion. A faceplate is generally provided, and suitable drivers for the large diameter wheels, and also a support to place behind the rim of the wheel to take the thrust of the cut. One maker of large machines of this type provides a vice which automatically grips the rim of the wheel being cut, after each dividing, so that the heaviest cuts can be taken without fear of possible error due to the wheel moving while cutting. Intermittent dividing mechanism is sometimes provided on these machines, because when cutting large wheels the rims become heated, and if adjacent teeth are cut all the time, then by the time you have cut round the wheel the teeth may not finish in pitch, owing to the expansion which takes place, due to the heat generated by the cutter. Machines of this type are made in a large range of sizes, which deal with the smallest pinions up to wheels about 9ft. to 10ft. diam.

Machines are in use for cutting the largest mill gears up to 25ft. to 30ft. diam. They deal with wheels with the teeth roughly cast out, and are provided with slotting or planing attachments which first roughs off the scale, and the finishing cut is taken with large formed cutters. These

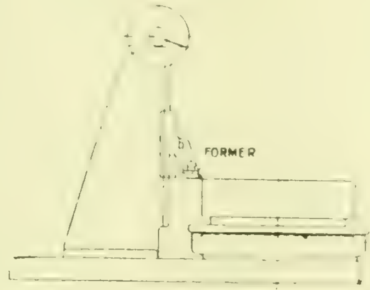


FIG. 18.

FIG. 19.

cutters are made in halves, and are packed out to correct thickness after sharpening. The cutters used in these very large machines are also made with inserted blades, and large end mills have also been used for large pitches

SPUR GEARS (PLANED).

It is necessary to subdivide the planing of spur gears into three sections: (*a*) Planing with shaped tools; (*b*) planing from formers; (*c*) the planing generating process.

(*a*) *Planing with Shaped Tools.* — The planing of spur

gears with shaped tools is a very old process. The principles employed are exactly the same as cutting with disc cutters, the tool being shaped to the tooth space in a similar manner to the cutter. The chief difficulty to contend with when cutting with this method is retaining the shape of the tool. It is a process which is still largely employed for cutting internal gears, the machine being generally in the form of a slotting machine; in fact, with a slotting machine with a suitable circular table for supporting the work, and a good dividing apparatus, very passable gears can be cut, both internal and external, particularly when roughing and finishing cuts are taken, which is a necessity if good gears are required. It is the most general method of cutting internal gears over about ¾in. pitch at the present time.

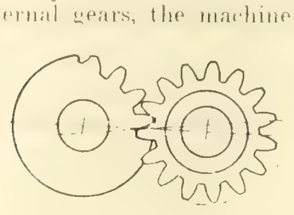


FIG. 20.

(*b*) *Planing Spur Gears with the use of Formers* is a method which at the present time is very much in use for cutting large gears, and some very large machines are made which work on this principle. One type of machine cuts gears from 10in. diam. to 20ft., and from about ¾in. to 6in. pitch. In the large pitches the teeth are roughly cast out, and a roughing cut is taken to remove the scale, and a fine finishing cut to get the final shape. The forming arrangement is made so that one pair of formers cuts all pitches on the same diameter of gear. The tool, which is carried on a suitable slide, is given a reciprocating motion, similar to an ordinary shaper or side planer. An auto feed is given to the tool slide, and as the tool feeds it is lifted by the bowl which runs on the former, thereby copying the shape of the former at the point of the tool. The bowl is kept on to the former by a suitable spring arrangement. One former is used for one side of the tooth, and another for the other side. See Fig. 17. The indexing is not automatic, but is operated by power, and is set into motion by the operator for each tooth.

Fig. 18 shows a diagram of a Newton machine, which works on a similar principle, only the wheel is mounted horizontally and the tool reciprocates vertically, similar to a vertical planer. This machine carries two formers, and finishes one side of a tooth at once. The operation is similar to the previous machines with regard to the casting out of the teeth and the roughing and finishing cuts. Fig. 19 shows the arrangement of the formers on this type of machine. It will be obvious that by laying out special shapes of formers any desired shape of tooth can be obtained. This makes the machine a most suitable type for cutting gears to meet specifications and for special work.

(*c*) *The Planing Generating Process.*—Within the last few years this process has been very largely developed, and to-day the author does not hesitate to say that some of the most accurate gears which are made at the present time are produced by this method. One class of machines work on the principle of a wheel rolling into another wheel or rack, as Fig. 20, and the other employs the principle of a rack rolling into a wheel and uses a cutter. Machines which work on either of the above principles cut all diameters of wheels and numbers of teeth of the same pitch with the same cutter or tool, and in generating the teeth the shape is correct for each particular number of teeth.

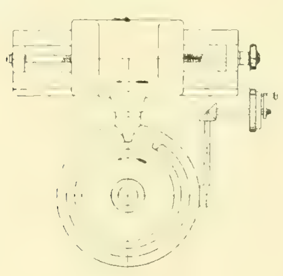


FIG. 21.

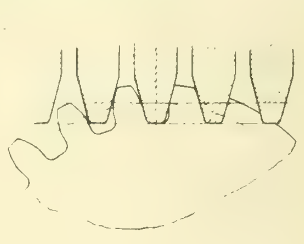


FIG. 22.

The Fellows machine works on the principle of Fig. 20. The most important thing is the cutter. This is made by special machinery, and the teeth are ground up by a generating process after hardening, to ensure extreme accuracy, and advantage is taken of the flexibility of the involute system in their manufacture, so that the sharpening does not affect the result when the gears are cut. The cutter is given a reciprocating motion similar to a slotting machine, and for ordinary spur gears generally cuts on the upward stroke for convenience of taking the thrust. It is also given a rotary motion, this being geared up to the blank at a correct ratio to suit the number of teeth to be cut. This rotary motion operates slightly at each stroke of the ram, and continues to do so until the blank has made a complete revolution. For specially accurate work the wheel is finished at twice round, the latest machines being provided with a special arrangement for taking part of the depth at the first cut round, and then automatically putting on a little extra as a finishing cut for the second time round. The machine with a special attachment will also cut racks on the same principle.

With reference to the machines which use the rack tooth as a generator, the simplest machine known to the author is in the form of a slotting machine, a shaped tool being mounted on the ram, and the wheel mounted on a suitable table. Fig. 21 shows a plan of the arrangement, and Fig. 22 the principle of its action.

The most modern machine which employs this principle is the "Sunderland" machine. The action of this machine is exactly the same as the last machine mentioned,

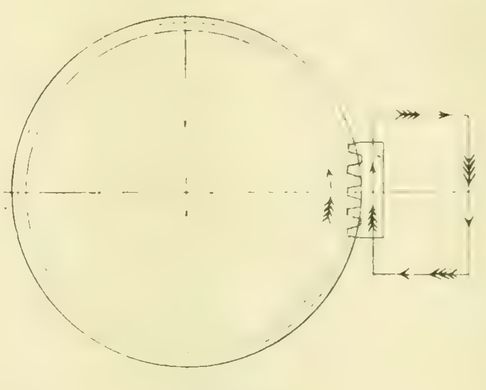


FIG. 23.

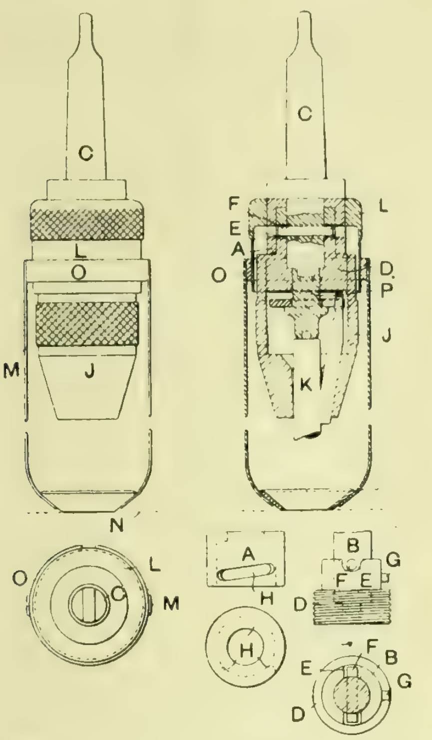
only instead of a single tool being used, a number of teeth are arranged in the form of a rack-shaped cutter. The teeth are accurately ground up to shape after hardening, and retain their shape after sharpening, the sharpening being done by means of a special machine which not only sharpens but grinds the cutting face hollow so as to give a cutting rake on the tool. For very accurate gears roughing and finishing cuts are taken, and the generating action is as follows: Referring to Fig. 23, the tool is carried in a slide which is given a reciprocating motion by means of a suitable crank and connecting rod. It has also vertical movement in relation to the wheel to be cut, governed by change wheels according to the number of the teeth to be cut. Starting with the tool in the lowest position it is sunk into the correct depth and then the feed set in motion. The tool is then carried by its support in a vertical direction, the blank revolving at the same time geared to it. After feeding in this manner for a suitable distance to generate one tooth, it withdraws out of the tooth, drops back one pitch, sinks in again, and proceeds as before, repeating the cycle of operations until it has cut the whole of the teeth in the wheel. One feature of this machine is that the dividing of the wheel takes place gradually and slowly during the cutting, the movement of the tool from one tooth to the next being given to the cutter head. This is a feature of the machine which is a consideration when dealing with very heavy gears of large diameter. These machines are made to cut up to 4in. pitch and about 10ft. to 12ft. diam. The large cutters are built up, a number of teeth being mounted on a suitable back or holder, thus saving steel and making a very cheap cutter to produce.

(*To be continued.*)

CHUCKS FOR BORING AND DRILLING MACHINES.

The chuck or tool holder illustrated herewith, the invention of Mr. H. P. Swinburne and Mr. G. S. Crawford, 89, James Street, Bridgeton, Glasgow, has been designed for use in connection with boring, drilling, and similar tools. The novel feature of the arrangement is the means provided for engaging and disengaging the tool and its holding mechanism from the driving spindle and its mechanism.

Referring to the illustrations, the inner sleeve A is mounted on the lower end B of the driving spindle C between



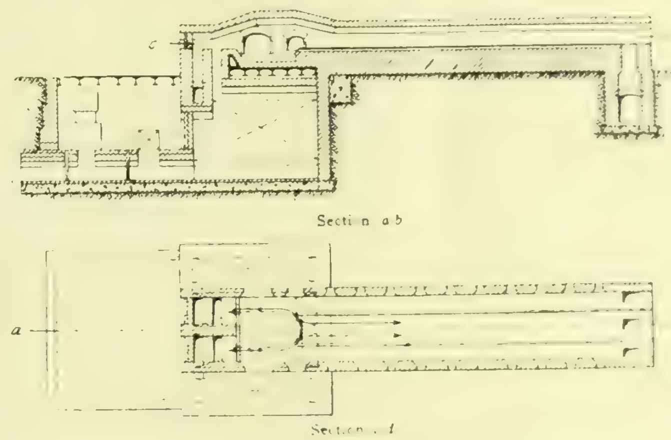
Chuck for Boring and Drilling Machines.

collars so that it has practically no longitudinal movement on the spindle, although it is capable of a rotary movement on same. The lower end B of the driving spindle engages with and drives the tool-holding device D, the upper portion of which is of sleeve or socket formation which embraces or encircles the spindle end B and which is formed at its upper end with notches E which engage with a pin F passed through the spindle end B so that when the pin F is in engagement with the notches E of the tool holder D and the spindle C rotated, the tool holder will be rotated also. In order that the pin F will be disengaged from the notches E so that the tool will not be revolved as the spindle C revolves, a pin G secured near to the upper end of the tool holder socket works in an inclined slot H formed in the inner sleeve A, so that if the spindle end B and tool holder proper D are in engagement and are being revolved and the inner sleeve A is held by the operator the slot H in the sleeve A travels over the pin G in the tool holder socket and raises the pin F in the spindle end out of engagement with the notches E of the socket so that the tool holder proper D is disconnected from the spindle end B.

The tool-holding device consists of a cylindrical sleeve J partly conical within which wedges K are fitted which are tightened or pressed on to the tool shank by the rotation of the sleeve J. A plug is screwed into the upper end of this sleeve and the tool holder socket is formed in one with or fitted into the upper end of the plug D. A sleeve L mounted round the inner sleeve A is of a tight fit so as to form a grip for the operator when he desires to hold the inner sleeve; and if desired, these sleeves may be held from rotating by automatic means instead of by the operator manually. This automatic means may consist of downwardly projecting members M secured to the outer sleeve L and adjustable as regards length, which comes into contact with the surface N of the work when the drill or other tool has reached the desired depth and thus prevents the sleeve L from being rotated which disengages the tool holder D from the driving spindle C. These downwardly projecting members M are adjustable as regards length by means of an ordinary pin and slot or screw arrangement, or, as shown, their upper ends may be secured to a spring collar O adjustable as regards its position on the outer sleeve L, or both arrangements may be used if desired. The pin F on the driving spindle end B and the notches E on the socket of tool holder D may be used in conjunction with the usual driving means P between the spindle end B and the tool shank.

SIEMENS' REGENERATIVE CONTINUOUS-HEATING FURNACE

Mr. Frederick Siemens, of Berlin, describes in a recent issue of "Stahl und Eisen" a new regenerative furnace which he has designed, and of which a number have been constructed for works on the Continent. The diagrams herewith show clearly the construction. The flame is divided. One part continues and flows through the furnace and the other turns in a horseshoe and passes through the waste gas ports, which are by the side of the incoming ports. Only the part that enters the regenerators comes in contact with the heated steel, and so is especially suitable for heating the checker brick. In this way a proportionately small flame serves to keep the regenerators at the highest temperatures. The furnace works with natural draught. There is a positive pressure in the high temperature of the hearth, so that as the heated steel is removed no outside air enters. The position of the four regenerators is shown on the illustrations. The arrangement of gas and air valves is the same as in the ordinary open-hearth furnace, except that the ports are not at opposite ends of the furnace, but side by side at the discharge end. The arrow shows the course of the flame which has been found to be the best under ordinary conditions. No systematic temperature measurements have yet been made, but the waste gases leave both the charging end and the regenerators at about 300° C., and the average temperature of the air is raised to about 1,100° C. It is claimed that in addition to saving in fuel, reduced scaling of steel, and lower repair



Siemens' Regenerative Continuous-heating Furnace

costs, the furnace can be easily regulated to meet changing conditions, such as, for instance, the heating of hard or soft, cold or hot material, in large or small billets. The furnace is suitable for the use of producer gas, coke-oven gas, blast-furnace gas, or mixtures of these gases.

Blast Roasting of Sulphide Ores.—In the course of a short paper on this subject recently presented before the Institution of Mining and Metallurgy, Mr. J. H. Levings described his experiences of this process in a Tasmanian smelting plant. He detailed how they came to abandon the use of limestone in the charge without deleterious results, and how [illegible] manganese ore was substituted. A further improvement in desulphurising was effected by changing the shape of the roasting pot or "converter" from that of an inverted cone to a nearly hemispherical shape, and a much better product was obtained for charging in the blastfurnaces.

TROUBLES WITH ELECTRIC MOTOR WINDINGS.

THE following interesting notes relating to a few of the types of trouble which have been experienced in stator and rotor windings of 3-phase plant appeared in a recent issue of "The Times Engineering Supplement."

Mechanical Weakness.—It appears to be sometimes forgotten by manufacturers of 3-phase machinery that the motors they make cannot always work under perfect conditions as regards installation, more particularly if they are required for factory purposes, inasmuch as perfectly rigid foundations and ideal conditions of temperature cannot always be secured. For this reason a good many machines which behave most satisfactorily on the test bed subsequently develop weaknesses which may really be traced to a certain lack of strength in the design. This is particularly noticed in some types of stator windings for large machines. In one particular instance a faulty arrangement for holding the coils in a large stator gave a considerable amount of trouble. The coils were held in place by means of a slight groove cut in the slots of the iron circuit, into which a piece of fibre $\frac{1}{16}$in. thick was driven after the coil had been placed in position, the fibre acting as a sort of top surface to it. This can hardly be described as a very strong method of securing the coils, and in the case cited it was found that after about three months' running, owing to the warming up which took place, the coils expanded and pushed the fibre out of the slots, especially at the corners. The absence of any restraint at this portion of the winding allowed the coils to come down and eventually to rub on the rotor, weakening the insulation, and ultimately causing earths. Efforts made to get the coils back again into their place and to insert new fibre slips proved quite useless, and in order to overcome the trouble it was found necessary to cast a ring of brass, made cone shaped, so as to take the ends of the coils outside the stator. This cone was thoroughly insulated with mica before being put in and fixed to the coils, and the additional support it gave prevented the coils from dropping down any further. Owing, however, to the expansion which had occurred before this device had been arranged, it was found necessary, in order to give the rotor sufficient running clearance, to turn off $\frac{1}{16}$in. from its surface, and of course in this way the characteristic of the machine was altered to some extent, owing to the increased air gap between the stator and rotor iron.

Defects in Insulation.—A good many motors which are made for factory purposes are installed in situations where, by the nature of the processes involved, they are necessarily subjected to high temperatures combined with a certain amount of humidity in the atmosphere, and similar conditions may arise also in the case of motors which are made for export and which are eventually installed in tropical climates. In such situations a considerable amount of weakness in insulation has been traced to the use of materials of an absorbent character for slot insulation in stators. The use of these materials is perfectly legitimate in ordinary circumstances, but where the motor is to work in the severe conditions mentioned above, a material which is of an absorbent nature is not the best to adopt, and a considerable number of breakdowns will probably be found to have been caused by the use of such materials in such circumstances. In some cases where motors have failed in this way they have been rewound with micanite insulation only, used next to the wire, and the insulation tests have then always been found satisfactory, even after protracted use, whereas with the materials referred to above it has been in some cases impossible to get an ohmmeter reading of any considerable value.

Motor designers are aware that so far as possible wires or bars in the conducting circuit which possess any considerable voltage between them should be kept as far apart as possible, but not infrequently owing to inadvertence or accident this precaution is not observed, and frequent breakdowns of windings in rotors and stators have been traced to one section of the windings short circuiting to another adjacent section which may have been wound over it. This is not always a fault simply of the design, since with ordinary care in manufacture it is possible to insulate so thoroughly that breakdown need not occur, but in some instances the risk caused by the adjacence of different potentials is aggravated by a slight absence of care in the choice and use of materials. In one such instance copper bars were employed for the windings of a large motor, and the sectors connecting one bar to the next bar in the circuit were also made of copper bar. Unfortunately, however, the edges of these sectors were rough. They had not been cut straight, and the precaution of floating them with solder had not been taken. The result of this neglect was that the vibration caused the insulation to rub away, and the bar became short circuited to an adjacent one. The damage could not be repaired without taking out a considerable portion of the winding, and the engineer in charge of the installation unwisely took the risk of allowing the motor to run. The result was that it became useless, and it therefore became necessary to rewind the rotor completely. When this was being done care was taken to avoid the evils mentioned above, and the spaces between the bars were carefully packed so as to avoid mechanical abrasion. As an additional precaution extra bands were put on the rotor to minimise the effect of vibration, and when this had been done the motor ran again without any further trouble from this cause.

TEST OF A STEEL OVERSHOT WATER WHEEL.

A SERIES of tests on a 10ft. steel overshot water wheel have recently been completed at the hydraulic laboratory of the University of Wisconsin, the results of which are recorded by Mr. C. R. Weidner in a recent issue of "Engineering News." The overshot water wheel is considered by some as out of date. It is, however, still capable of serving a distinct field, where the power to be developed is small and the speed of the machinery is slow and requires but little regulation. The fact that wheels of this type are still being installed, after careful engineering investigation, for small factories, pumping plants,

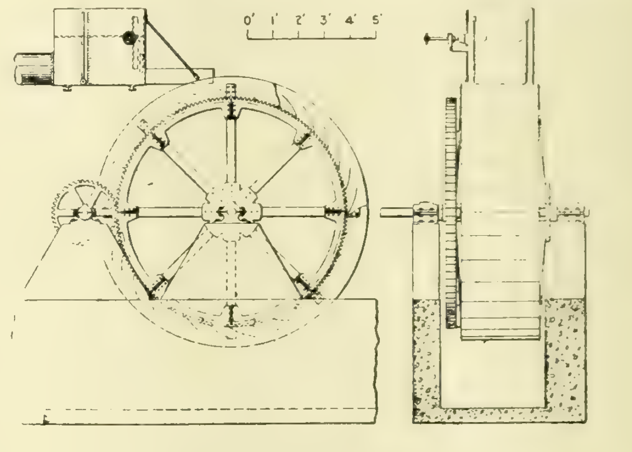


FIG. 1.—STEEL OVERSHOT WATER WHEEL.

and even for the development of electrical energy, may be taken as an indication of satisfactory and economical use of this type of motor.

The overshot wheel was formerly constructed of wood. In recent years, however, the wheel has been built entirely of steel and iron. Although the initial cost of a wooden wheel is less than one built of steel, the latter possesses certain advantages which make it more desirable to install, notwithstanding the increased cost. Unless a wooden wheel be kept continually in operation, the constant swelling and drying of the wood soon causes all parts to get loose; the buckets leak and a considerable percentage of the available energy is wasted. In a steel wheel the buckets can be shaped more readily to accord with the design; a larger percentage of the total head is made available on account of the smaller thickness of the metal; and the friction in the bearings is decreased because a steel wheel is lighter than a wooden wheel well soaked with water. For these reasons the steel wheel is more efficient. Moreover, it is more durable, the cost of maintenance is less, and the parts are more readily assembled.

Fig. 1 shows an example of a steel overshot wheel of modern design—the wheel tested at the University of Wisconsin. The buckets are formed by curved vanes attached to the cylindrical surface or inner circumference of the wheel, called the soling, and to the segmental circular housings on the sides. The vane thus forms the front or outer part of the bucket, the soling the back or inner side, and the housings form the sides. The buckets, soling, and rims are made of

flanged steel riveted together. To the housings are bolted the radial arms, made of flat bar steel, which in turn are bolted to cast-iron centre flanges keyed to the shaft. Power is usually taken from the wheel by means of gearing and is transmitted by shaft, belt, or rope drive. In some designs the segmental spur gearing is bolted to the arms of the wheel, in others a gear wheel is keyed directly to the shaft. The manufacturers furnish either ball or roller bearings as specified.

The advantages of the overshot wheel are: (1) High efficiency; (2) adaptability to varying discharge; (3) simplicity in construction; (4) reliability; (5) no interference of operation on account of clogging with débris or ice. Of these advantages the first two are of the greater importance. The results of the experiments discussed below show high efficiencies under a wide range of operating conditions. Reliable tests of turbines have been reported yielding as high as 89 per cent. efficiency, but it is rarely that this figure is attained in an actual installation. In the smaller plants especially, where an overshot wheel would be capable of competing with a turbine, it is doubtful whether the turbines operate with an average efficiency higher than 70 per cent. It is, however, extremely difficult to make any comparison as to the efficiency of two types of motors, unless both have been tested under exactly similar conditions of operation. The installation of a turbine requires a technical analysis of the problem, and unless the turbine is set properly and selected for the particular conditions under which it is to operate, the efficiency will fall far below that of which it is capable when operating under the proper conditions. Very few of the small water powers developed receive the proper engineering supervision to promote a high degree of efficiency in their operation. The overshot wheel, on the other hand, suffers but little from a lack of proper design or selection, although to obtain the highest efficiencies of which the wheel is capable, it is not advisable to dispense with a technical analysis.

To engineers familiar with the variation in efficiency of the turbine at part gate, a glance at the curves obtained from the Wisconsin experiments (Fig. 2) will be convincing as to the superiority of the overshot wheel, in respect to its adaptability to varying discharge. The experiments show that the range in the discharge may be as much as 400 per cent. with only a difference of 5 per cent. in the efficiency of the wheel. The other advantages cited are of minor importance, though in particular cases they may influence the choice of type of motor to be selected.

The limitations or disadvantages are: (1) An economical limit in respect to the head and discharge to be developed; (2) a limit in respect to the speed of the machinery to be operated; (3) a limit in respect to the variation in the water levels in the head and tail races; (4) larger space requirements than a turbine.

On account of the increase in the weight of the wheel, as the head or discharge is increased beyond a certain limit, the cost of the overshot wheel becomes so great that it can then no longer compete advantageously with the turbine. The economical field of the wheel, therefore, lies in developments which range approximately between 2 cub. ft. and 30 cub. ft., per second discharge, with heads varying from 10ft. to 40ft., corresponding to a maximum development of about 75 h.p. Within this field, the question whether to install a water wheel or turbine must be decided on the basis of the particular conditions of the power to be developed, the class of machinery to be operated, and the cost of installation. Only a rough approximation can be made as to the cost of the two types of motors, from the figures furnished by the manufacturers. In general it may be said that the initial cost of an overshot wheel, up to a diameter of 16ft., will be about twice that of a turbine of equal horse-power, and above that diameter a little more than twice the amount.

The peripheral velocity of the overshot wheel, when operating efficiently, varies approximately between 3ft. and 7ft. per second, depending on the diameter, discharge, and velocity of the entering water. Hence, there would be a practical limit to the speed of the machinery to be served, beyond which the loss of power through the necessary gearing would probably offset any gain in efficiency. It is, therefore, particularly adapted for the operation of slow-speed machinery, and should find a field of usefulness for the operation of small factories, the machinery on farms or country homes, and especially for pumping plants, where the pumps may be connected directly to the wheel shaft. For the operation of high-speed machinery, a loss of from 3 to 10 per cent. may be estimated to occur through the necessary gearing or belting.

The principal application or use of water power at present is the development of electrical energy. In general the opinion is held that only turbines on account of their high speed are applicable for this purpose. However, a number of electrical plants, operated with water wheels, have been built and are giving satisfactory service. The inertia of the heavy wheel and gearing provides a very uniform motion, and high efficiency at part load is a very desirable feature in electrical plants. It is a matter for the designing engineer to decide which type of motor will give the highest total efficiency for a plant of this kind.

The efficiency of the overshot wheel drops off quite rapidly if the bottom of the wheel is submerged, even though this is

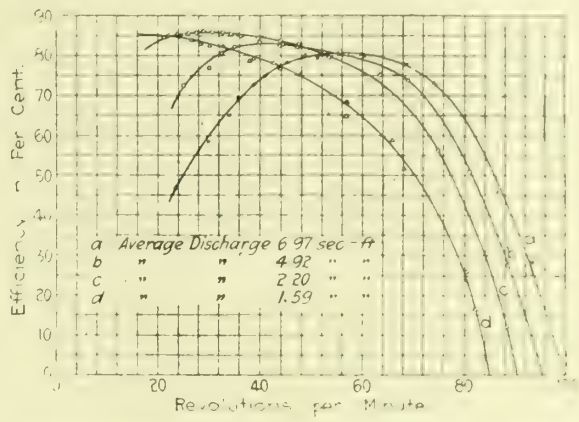


FIG. 2.—EFFICIENCY-DISCHARGE CURVES OF A STEEL OVERSHOT WATER WHEEL (POWER MEASURED AT JACK SHAFT.)

but a few inches; therefore, the wheel is poorly adapted to conditions where there is a considerable variation in the tail-water level. The turbine will operate almost as efficiently when submerged as when not submerged, and by use of the draught tube there is but little occasion to have it submerged. In this connection it should be noted that in periods of flood, when the water wheel is likely to be submerged, there is an excess of water, and as the wheel is particularly adapted for overload capacity, the extra power developed would probably make up for any decrease in efficiency.

Within these limitations the overshot wheel is capable of serving a field in water-power development, and of competing successfully with the turbine both in efficiency and cost of operation. The decision as to water wheel or turbine must be made after careful investigation of the particular conditions to be met with; each type of motor should receive equal consideration. The considerations which influence this choice are: (1) Head and discharge available, and probable variation in these; (2) cost of the motor, including setting and foundation; (3) relation of motor cost to available capital for plant construction; (4) class of machinery to be served, and whether continuous or intermittent power supply is required.

Laboratory tests of a machine, when properly interpreted, undoubtedly have a great value, but it must be borne in mind that any test so made represents results under the exact conditions of the test. The conditions under which the Wisconsin experiments were performed approached practical conditions very closely. The wheel tested was of a standard pattern taken from the stock of the manufacturers. The structural features are simple, and none of these features of the wheel itself were changed during the tests. Apart from the structural features of the wheel, the chief factors which influence the efficiency are the velocity of the entering water, the relation between this velocity and the peripheral velocity of the wheel and the discharge. The results should, therefore, be readily duplicated in actual service, if the wheel is set properly, and they may be taken as a guide in the design and installation of this type of water wheel. A summary of the conclusions reached in the experiments, the details of which will be published in a University bulletin,* is given below.

(1) The maximum efficiency obtained was 89 per cent. of

* "Theory and Test of an Overshot Water Wheel," by C. R. Weidner. Bulletin of The University of Wisconsin, No. 529.

the theoretical input delivered at the wheel shaft, or 86 per cent. at the jack shaft.

(2) The transmission loss, through the spur gear and pinion, including the friction in the bearings, reduced the efficiency of the wheel 3 per cent. at maximum efficiency of operation. Within the limited range of the experiments this loss increased with the speed and decreased with the horse-power transmitted.

(3) The efficiency of the wheel, other conditions remaining constant, increased with the decrease in the entrance velocity of the water. This statement is limited, however, by the fact that for maximum efficiency a definite relation exists between the peripheral velocity and the entrance velocity, so that a limit is reached when the entrance velocity equals or slightly exceeds the peripheral velocity.

(4) The variation in the discharge within reasonable limits, so that the coefficient of filling does not exceed approximately 0·50, has little if any effect on the efficiency of the wheel.

(5) For maximum efficiency of operation the ratio of the peripheral velocity of the wheel to the velocity of the entering water is a constant, whose value is approximately 0·90.

(6) Submergence of the wheel in the tailwater causes a serious decrease in the efficiency. A submergence of 3in. caused a loss of 6 per cent. at maximum efficiency of operation, which loss increased rapidly as the submergence was increased.

(7) For maximum efficiency, the point of impact of the water should lie as high in the wheel as possible. The point is regulated by the distance of the entrance spout or orifice from the wheel, and must be adjusted, otherwise a serious loss of energy occurs at entrance.

DESIGN OF SURFACE CONDENSERS.

BY W. H. BOOTH.

In designing surface condensers the main object generally seems to be to put the largest possible surface in the direct path of the steam irrespective of any consideration for the passage of steam beyond the first row of tubes. About the only concession in this direction is the omission of a group of tubes so as to produce a gap of V-form in the general mass of tubes. These gaps serve to present more tube surface on the one hand, while on the other they provide more passage-ways by which the steam can reach the interior of the nest of tubes.

Yet the modern steam turbine is found to be so arranged as to provide a pipeway to such a blocked condenser, the full diameter of the turbine rotor. If so great a diameter of this detail be desirable, it is not consistent that the passage-way between the condenser tubes should be so much reduced. Experience also points to the error, for the vacuum differs by as much as an inch between the steam entry and the base of the condenser. Except for the considerations of cost and space, there is no reason why a condenser should not be many times its ordinary cubical capacity with widely-spaced tubes dispersed throughout the space. If steam be regarded in the light of the kinetic theory of gases, the molecules of which are darting about at a velocity of perhaps 1,800ft. per second, is it not obvious that an extra few feet of length or breadth will have little effect upon the time required by each molecule to find its way to a cold tube surface? The ideal condition would be that each molecule touch a cold surface which would kill its self-translatory activity and drop it to the condenser base as so much dead water.

Every tube carrying a stream of water possesses a certain capacity for absorbing heat from the molecules which pass upon it. But if too many molecules strike the tube in a given time the tube surface will become hot, for there is a limit to the rate of heat conduction through the walls of the tube. From the hot surface the steam molecules will rebound without having given up much of their heat energy, and in the rebound they will strike against the oncoming stream of molecules from the cylinder, driving these back to some extent, or at least hindering their flow. Undoubtedly the major portion of the work of a surface condenser is accomplished in the first row of tubes, and the result is this reflex action of many of the molecules which ought never to have hit any of the first row of tubes, but should have passed forward to the second, third, and subsequent rows. What seems to be needful is that only one tube in three of the first row should remain, and this tube should be fitted with a light casing of thin metal with lips placed vertically toward the flow of steam. In cross-section this casing would resemble the letter A with an open top. The tube would occupy the lower division of the letter, which would rest upon the tube by means of an occasional crossbar. The top slot would have a breadth of, say, a fourth or a third of the tube diameter, thus reducing the number of molecules which reach the tube surface, and therefore keeping down the temperature of that surface so that it ceases to be a surface from which molecules can rebound with any great velocity. In this way the amount of steam dealt with by the first row of tubes is reduced to about one-ninth or one-twelfth of the old arrangement. The next row of tubes would be similarly spaced and fitted, and so also the third, or even the fourth rows; beyond that the spacing would become closer and the covers made with wider slots, or even omitted, and so on to the base of the condenser, where the tubes would be closely spaced.

The provision for wider spacing is particularly desirable where the contraflow principle is employed, for if this is fulfilled the first tubes touched by the steam are the hottest, and create the maximum of reaction. Since the temperature of saturated steam is fixed for any given pressure there can be no temperature difference without a pressure difference, and the contraflow principle presupposes such a pressure difference and indicates a loss of vacuum in the cylinder. It seems more rational that the first rows of tubes should be as cold as possible, and that the last rows should be cold also. Any marked rise of temperature of the circulating water should be in the middle tubes, where most of the steam has disappeared, and the passage way is ample for what is left. There appears to be no difficulty in designing a condenser on these lines to provide for intercepting the water condensed in each division, so that it shall not drip on the tubes below. Summarised briefly, the suggestion is that the spacing of the tubes should be wide in proportion to their nearness to the cylinder, and that the passage-way should diminish as the steam diminishes in quantity.

If a 2in. vacuum is attainable under certain conditions, and there is an absolute pressure of 3in. at the top row of tubes, the steam volume per unit weight will be 50 per cent. greater at the lower tubes, and should be provided for accordingly. But such a loss as 1in. is what the suggested design aims to avoid by the provision of ample space for the passage of the steam. In practice it appears probable that such a design would culminate in condensers having a maximum of passage area transverse to the path of the steam, so that the condenser would be long and wide in order that the first rows of tubes should still possess considerable surface even though the tubes were not allowed to exceed a given fraction of their full duty, as provided for by the cover sheds.

Steam is perhaps best distributed over the upper row of tubes by providing for its entry above the tubes and parallel with them in a wedge-shaped chamber extending the length of the tubes. If admitted to the central part of the area of the upper row of tubes it should be by a tapering entrance or a reversed hopper springing from both ends of the tubes and fitted with diverging plates to spread the steam throughout the length of the upper row. Baffleplates across the path of the steam are bad practice, and serve to cause obstruction. It is better to guide the steam than to compel it to spread by the interposition of a baffle.

The ideal condenser is, of course, a large open chamber with cold walls, into which steam is admitted, and speedily finds one of the six cold walls. A large cubical room with about 45 sq. ft. on each wall would give only the 12,000ft. of surface regarded as necessary for a tubular condenser occupying a mere fraction of this volume. Even cellular, flat internal walls would diminish the volume very little, and it is not easy to escape from the tubular design. But this has been overdone to the extent that tubes have been spaced too closely to permit the vacuum formed at the base to act upon the cylinder.—"Power."

INDUSTRIAL AND TRADE NOTES.

Safety Lamps in Mines.—The Home Secretary gives notice that he has made an order, under section 33 of the Coal Mines Act, 1911, approving, subject to the conditions specified in the order, the Hailwood lamp No. 1, and the Oldham emergency electric lamp for use in all mines to which the Act applies. The Oldham lamp is approved only for use in the work of rescue or exploration in the case of an accident or other emergency, or by officials. The official specifications of these lamps, with plates showing the general design of each, are contained in the order, copies of which will shortly be placed on sale.

Accidents in Mines and Quarries.—An advance proof has just been issued by the Home Office of tables prepared under the Coal Mines Act showing the number of fatal accidents and deaths in and about the mines and quarries of the United Kingdom during 1912. Under the Coal Mines Act there were 1,113 separate fatal accidents, causing 1,268 deaths. The totals in the preceeding year were 1,212 and 1,265 respectively. Of the total number of accidents in 1912, 971 were underground, 547 of them being due to falls of ground, 70 were shaft accidents, and 20 were explosions of fire damp or coal dust. In the metalliferous mines there were 40 separate fatal accidents last year, as compared with 41 in 1911, the number of deaths being the same in each year 43. There was a total of 70 separate fatal quarry accidents last year, as compared with 96 in the preceding year. There were 73 deaths from the accidents, compared with 99 in 1911.

Machine Tool & Engineering Association.—Since the last annual report, the directors say, 23 firms have joined this Association, bringing the membership up to over 100. The balance in hand, after meeting all current liabilities, is £3,954. The exhibition at Olympia was successful. The total number of exhibitors was 292, the total attendance of the public about 100,000. The directors fully realise that owing to the want of adequate handling appliances the cost to members of installing their exhibits was unduly high, but care will be taken that this shall not recur in connection with future exhibitions. The Association was approached by the Exhibitions Branch of the Board of Trade with the view of joint action in organising a collective exhibit of machine tools at the Ghent Exhibition, and the suggestion was approved by the Association, but when invitations to apply for space were sent out to the members the response was so inadequate as to make it clear to the directors that a representative display was impossible, and the scheme was therefore abandoned. The directors have accepted the invitation of the British Empire Trade Mark Association to join the Provisional Council of that Association.

Development of Tramways.—The annual return of capital and traffic for 1911 and 1912 of tramways and light railways (street and road) just issued shows that since the year 1878 the route length of tramways and light railways on public roads open for traffic in the United Kingdom has increased from 269 miles to 2,637 miles, and capital expenditure from £4,207,350 to £77,377,390; the number of passengers carried from 146 millions to 3,127 millions; and the net receipts from £234,956 to £5,801,618. Of the total of 1,777 miles of line owned by local authorities 1,571 miles are worked by those authorities themselves or (in a few cases) by other local authorities leasing from them, and the remaining 206 miles by leasing companies. Last year the route mileage worked by electric traction was 2,467 miles, out of a total of 2,597; this year it is 2,518 miles out of 2,637, the remainder being 1·5 per cent. of the total length of line. Of the 290 undertakings, 172 belong to local authorities and 118 to companies or other parties. In the cases of three local authorities and six companies the returns show an excess of working expenditure over gross receipts. The percentage of working expenditure to gross receipts was 60·60, as against 61·70 in 1910-11. The return states that although there had been a small increase in the rate of capital expenditure per mile of route open and an increase in the number of passengers carried per route mile and per car mile, coupled with a decrease in the ratio of working expenditure of gross receipts, the net receipts improved to such an extent as to afford a better percentage on capital outlay than was shown in the return for the previous year.

A Weighing-machine Patent. Action by Messrs. W. & T. Avery.—In the Chancery Division, on the 17th inst., Mr. Justice Neville delivered judgment in the patent action of W. & T. Avery, Ltd., v. H. Pooley & Son, Ltd., both of whom are well known weighing machine manufacturers. The plaintiffs asked for an injunction restraining defendants or their agents or servants from infringing plaintiffs' patent, damages and delivery also being claimed. The patent in question comprised an ingenious device for weighing trains, trucks, and other such heavy things at receiving depots and collieries. The principle of the invention was the construction of two weigh-bridges and three steel yards. By those means the weight could be ascertained of two trucks, either separately or combined. Mr. Dugald Clerk, consulting engineer, said plaintiffs' invention was an important improvement on other schemes. The defendants urged that there had been no infringement. Platforms and steel yards had been used before, and the addition of an extra steel yard could not be called an invention. His Lordship, in giving judgment, said that all the methods in existence of weighing trucks up to this patent left something to be desired, because there was no machine in existence that could weigh either a combined load or two separate loads according to the will of the operator, without the necessity of detaching the trucks from the train. A useful purpose was achieved by this machine, and obviously it was a new machine, and also obviously it was a machine that at the time was unknown. It was quite true it was a small advance upon the machines already in existence, but it was an advance and a useful advance, and it required the exercise of invention to give effect to it. The plaintiffs had come to the rescue in the difficulty that existed, and the way they had solved it was by having three steel yards in connection with two weigh-bridges, and that entitled them to their monopoly. The plaintiffs were right in their contention that they had a good patent, and they were entitled to the injunction with costs and enquiry as to damages. Leave to appeal was granted.

British Trade with Continental Countries.—The Board of Trade have issued a return showing the value of the goods, wholly or mainly manufactured, imported from the United Kingdom into France, Germany, Belgium, and Holland in the years 1881 and 1911 respectively; and the value of goods wholly or mainly manufactured exported to the United Kingdom from each of these countries in the same years. The following are the particulars:

(a) Special Imports from the United Kingdom.

Country.	1881.	1911.
Into France	£13,221,000	£17,938,000
,, Germany	9,310,000	21,089,000
,, Belgium	2,728,000	5,151,000
,, Netherlands	13,320,000	11,365,000

(b) Special Exports to the United Kingdom.

Country.	1881.	1911.
From France	£17,789,000	£31,710,000
,, Germany	13,583,000	11,325,000
,, Belgium	5,816,000	13,210,000
,, Netherlands	5,153,000	23,898,000

The above particulars have been compiled from the official trade returns of the countries specified. The values given to exports from Germany in 1911 were in general those declared by the exporters. The other figures relating to Germany and all those relating to France and Belgium represent the results of calculations based upon official estimates of the average values in each year of each description of article. In the Netherlands a schedule of value is in use for the purposes of the official trade statistics which remains substantially unaltered from year to year. The figures, therefore, though useful as indicating the growth of trade with the United Kingdom between 1881 and 1911, are not to be taken as representing actual values.

Mines Inspector's Appeal Dismissed. Judgment was delivered on the 17th inst. in the appeal of Mr. John Atkinson, inspector under the Coal Mines Regulation Act, from a decision of the Gateshead magistrates, who had declined to convict Mr. H. M. Imrie, the manager of the Chopwell Colliery, for an alleged offence under the Coal Mines Regulation Act. The case was heard by the Divisional Court some time ago, and the question was whether an electric switch box in the mine should have been earthed. It appeared that an employé touched the box, and was fatally injured, and the manager was summoned for an offence under the electricity section of the Act, the contention being that the switch was part of an installation system, and should have been properly earthed. For Mr. Imrie, it was argued that the switch was merely a part of the electrical construction, and that, this being so, the rules requiring the earthing of the apparatus to the insulation system did not apply, as the apparatus had been constructed before 1911. The magistrates had refused to convict, and from that decision the inspector appealed. The court now dismissed the appeal, with costs, holding that the magistrates were right.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Valve mechanism for four stroke cycle internal combustion engines. Brasier. 23458.
Anti friction bearings. Greene. 25921.
Two stroke cycle internal combustion engines. Cloudsley. 26615.
Balancing of reciprocating engines. Lanchester. 26038 and 26777.
Radial multi cylinder engines and pumps. Sharp. 26823.
Furnaces. Zulver. 28730.
Rolling metals and mills and appliances employed therein. Doughty. 28777.
Worm gearing. Brown. 28814.
Machine tools. Gridley. 28829.
Force pumps. Anderson, Symes, and Midland Railway Company. 28851.
Steam generators for turbines. Wurtz. 28862.
Ore concentration. Chapman & Tucker. 28929.
Exhaust valves of internal combustion engines. British High power Gas Engine Company, and Neustadter. 28943.
Generation of combustible gas or vapour from liquid fuel. Biddlecombe. 29021.
Aeroplanes. Welford. 29058.
Water tube boilers. Maxted. 29183.
Supply of secondary air for combustion in boiler furnaces. Minorikawa. 29205.
Process of manufacture of artificial fuel and apparatus therefor. Graigola Merthyr Company. Yeo & Goskar. 29220.
Apparatus for regulating the temperature of molten metal. Weigert-Sterne. 29223.
Elastic coupling for motor gearing. Soc. Anon. des Automobiles et Cycles Peugeot. 29232.
Flying-machines. Mowbray. 29268.
Internal-combustion engines having sleeve valves. Belden. 29314.
Aeroplanes. Peláez. 29333.

1912.

Feathering devices for propellers and fans. Wilson. 11.
Steam generators. Pielock. 58.
Rock drills. Edgar. 77.
Variable-speed gearing. Heymann & Hartmann. 91.
Valve mechanism of internal-combustion engines. Rothchild and Jarvis. 179.
Rotary internal-combustion engines. Beeby. 203.
Internal-combustion engines. Seeley & Wood. 253.
Apparatus for evaporating sea water and for generating steam. Willis. 272.
Fluid-pressure operated cylinders and pistons. Craggs. 438.
Pressure-regulating means. Lloyd. 482.
Production of gas from hydrocarbon oils. McFarlane. 519.
Feed mechanism for machines. Pilkington. 532.
Railway rail joints. Kaylor. 610.
Flying-machines. Williams. 1324.
Governing mechanisms for centrifugal compressors. British Thomson-Houston Company. 1863.
Railway rail joints. Heywood & Thorpe. 2193.
Construction of ships. Carmichael. 2907.
Valve springs of internal-combustion engines. Ritson. 3153.
Locomotives. British Thomson-Houston Company. 3231.
Carburetters or vaporisers for internal-combustion engines. Morgan. 3486.
Apparatus for heating and pumping boiler feed water. Morison. 4547.
Calorifiers. Griffiths, Tennant, & Barrs. 4550.
Feeding and conveying apparatus for metal plate rolling mills. Gale & Whittle. 5518.
Means for controlling the air supply to tuyeres for cupolas. Davies & Davies. 5846.
Process for manufacturing plates for foundry use. Von Stein. 6631.
Lubrication of bearings. Geach. 7511.
Swivels for crane chains. Johnson. 7647.
Furnaces. Goldie. 7712.
Manufacture of superheater tubes. Frandsen. 8187.
Means for governing the speed of wind motors. Turnbull. 8789.
Belt conveyors. Afzelius. 10046.
Force-feed lubricators. Smith. 10998.
Steam boilers. Boult. 13033.
Wrenches. Gross. 14142.
Couplings for shafts. Kildear. 15210.
Turbines. McDougall. 16292.
Reducing valves. Saugey. 16503.
Liquid power transmitting apparatus. Zambon. 16785.
Starters for internal combustion engines. Volkmar. 17009.
Casting of steel ingots. Kohlhaas. 19657.
Supplying and vaporising fuel for use with internal combustion engines. Tangyes, Ltd., and Robson. 19695.
Rotary elastic fluid-pressure engines of the revolving-cylinder type. Da Costa. 22349.
Aerial propellers. Mack. 25939.

ELECTRICAL, 1911.

Electric switches. Whyman. 27251.
Magnetic separators. Fried. Krupp Akt.-Ges. Grusonwerk. 29201.
Apparatus for the magnetic separation of ores. Ullrich. 29230.
Electric safety lamps. Dickie. 29331.

1912.

Wireless telegraph receivers. Marconi & Franklin. 86.
Electric batteries. Liney. 181.
Electric heating elements. Townshend. 387.
Electric controller regulators. Sefton Jones. 523.
Aerial conductors used in wireless telegraphy. Marconi's Wireless Telegraph Company, Ltd., and Prince. 2456.
Electric arc lamps. Quint. 3065.
Means for supporting electric lamps. Byng & Collings. 7137.
Electric propulsion of vehicles, boats, airships, &c. Marino. 13780.
Induction electric furnaces. Bally. 16040.
Electro-magnetic track brakes. Magnet bremsen Ges. 26295.
Connection apparatus for electric circuit conductors. Murray. 26337.

METAL QUOTATIONS.

TUESDAY, JANUARY 21st.

Aluminium ingot	95/- per cwt.
„ wire, according to sizes, &c. ......from	112/- „
„ sheets „ „ ...... „	120/- „
Antimony ......£38/-/- to	£40/-/- per ton.
Brass, rolled	9½d. per lb.
„ tubes (brazed)	10½d.
„ „ (solid drawn)	8⅞d.
„ „ wire	8⅞d.
Copper, Standard	£69/2/6 per ton.
Iron, Cleveland	65/- „
„ Scotch	71/- „
Lead, English	£17/10/- „
„ Foreign (soft)	£17/3/9 „
Mica (in original cases), small	6d. to 3/- per lb.
„ „ „ medium	3/6 to 6/- „
„ „ „ large	7/6 to 11/- „
Quicksilver	£7/15/- per bottle
Silver	29d. per oz.
Spelter	£26/5/- per ton.
Tin, block	£226/10/- „
Tin plates	15/1½ „
Zinc sheets (Silesian)	£29/7/6 „
„ (Stettin; Vieille Montagne)	£30/5/- „

Micro-Motion Study.—A novel method of taking time studies has been introduced by Mr. F. W. Gilbreth and consists in the use of the cinematograph or moving-picture machine in conjunction with a special chronometer. This chronometer has a dial about 18in. diam., and is provided with a single pointer, which makes ten revolutions per minute. The dial is divided into 100 divisions, so that each division represents an actual time interval of one-thousandth of a minute. A moving picture is taken of any operation of doing work, the chronometer being placed alongside so as to include it on the picture. By this means the successive positions of the workman in performing each minute operation of his job are clearly shown on the film, while the length of time between each operation is shown by the position of the chronometer pointer in the successive films. These films are studied under a microscope after they are developed, and a careful analysis of each operation is made, and the standard time for each operation is easily obtained. The film also serves as an instruction card for the workmen, showing him not only what to do but how to do it, and the time in which it can be done.

The Mechanical Engineer.

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Edited by
WILLIAM H. FOWLER
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Condenser Explosions.

THE disastrous explosion of a condenser on the 6th inst. on board the French battle-ship "Messena," in Toulon Harbour, resulting in the loss of nine lives, revives interest in a question that has given rise to discussion and differences of opinion on several occasions amongst those responsible for the safety of the propelling machinery on board ship in this country, especially since the introduction of the steam turbine, where the possibilities of an excessive pressure accumulating is greater than in reciprocating motors. Some of our readers may remember that a few years ago the differences assumed a somewhat acrimonious form and that Messrs. Denny, of Dumbarton, appealed against a refusal of the Board of Trade to grant a passenger certificate for a new steamer they had built and equipped with steam turbines, on the ground that they did not comply with the official requirement for safety. In the hearing of that appeal there was considerable conflict of evidence as to the possibilities of danger, and although the Court sustained Messrs. Denny's appeal, the judgment was rather a reflection upon the harsh way in which the Board of Trade insisted upon the absolute letter of their regulations, than upon the actual need of them in spirit. We do not mention this case to revive any details of it, but it is interesting in view of events that have since occurred. In our issue of February 2nd last (page 122, Vol. XXIX.) we drew attention to a very disastrous turbine condenser explosion that had occurred in America, which by its violent and destructive character demonstrated the potentialities for disaster which turbine condensers afforded unless suitable precautions and margins of safety are adopted, and though up to the present such failures have been rare, the two alluded to show how terrible they may be. Strong objection has been taken by some to the Board of Trade regulation that a test pressure

See the "Mechanical Engineer" [illegible]

of 30lbs. should be applied, but, in view of the dangers attendant upon escape of steam in an enclosed engine room, we cannot think it excessive. We have no details of the causes which led to the disaster on the "Messena," but it may be presumed that, being a warship, no expense would be spared to provide what were deemed adequate precautions, and in view of this fact the failure emphasizes the necessity of guarding against them.

Locomotive Boiler Explosions in the United States.

WE have several times drawn attention to the extraordinary frequency of boiler failures in the United States, as compared with this country. It is true that country is much larger than ours and contains a proportionately greater number of boilers, but, making every allowance for this, and relying only on the unofficial and imperfect statistics gleaned from newspaper reports, the percentage of explosions in relation to the number of boilers employed is many times greater there than here. Some striking evidence of this is just furnished in the first annual report of the federal chief inspector of locomotive boilers for the year ending June 30th, 1912. Figures taken from this and published in the "American Railway and Engineering Review" show that the total number of locomotive boiler accidents alone amounted to 856, killing 91 persons, and injuring 1,005 others. No less than 90 per cent. of the fatalities which occurred were the result of failures either of the shell or the firebox crown plate, while three shell failures alone caused the deaths of 27 persons and injury to 41 others. Firebox crown failures as a result of overheating from shortness of water are, it seems, the most potent source of fatality and injury, a total of 94 of these resulting in 54 deaths and injuries to 168 others. In 69 of these cases the cause, so far as it was disclosed by inspection, was negligence on the part of the engine men or others in attendance, a state of affairs which suggests either a considerable degree of carelessness or recklessness on the part of the men employed, or absence of safety appliances in the shape of fusible plugs. It is certainly difficult to understand the frequency of such accidents in the States, in view of their comparative rarity here, unless it be that such fittings are either not generally adopted or so neglected that they are useless when an emergency arises. A notable feature of the figures given by our contemporary is the number of cases of injury arising from the failure of fittings and attachments, no less than 10 per cent. of the fatalities and 90 per cent. of the injuries being caused in this way; 165 cases of burst water gauge glasses, for instance, causing one death and injury to 168 others suggests that such an ordinary safety provision as a gauge protector is far from general, while other figures demonstrate equal carelessness in other directions. It is probable, however, now that the "bull's-eye" of a public department has been turned on to the defects of American locomotive equipment and working and the sad results arising out of them, that steps will be taken to effect improvement. There is obviously room for it in many directions.

THE SPONTANEOUS COMBUSTION OF COAL.

AT the Institute of Marine Engineers, Stratford, on Monday, January 20th, a paper was read by Mr. James E. Milton on "The Spontaneous Combustion of Coal." In the course of his paper, which treated the subject very exhaustively, Mr. Milton detailed the results of researches and investigations by Dr. Richters, M. Henri Fayol, M. Barrow, Prof. Vivian B. Lewes, the British Royal Commission of 1876, and the Royal Commission appointed by New South Wales in 1897. Among other conclusions derived from a consideration of these investigations, the author said it would appear that all classes of coal, bituminous or anthracite, absorbed oxygen to a greater or lesser degree. This absorption was accompanied by development of heat, an action which would be progressive if the heat was not abstracted as quickly as it was generated. All classes of coal were therefore liable, given favourable conditions, to spontaneous ignition. These conditions were dependent on the air supply, surrounding temperature, kind and size of coal. The through ventilation of a coal cargo was impracticable, and surface ventilation, supplemented as it frequently was by the opening of the hatches in fine weather, might aid the spontaneous generation of heat by supplying a slow current of oxygen through the mass of the coal. Efforts should be directed towards reducing the air supply in holds to a minimum. Bunker coal required different conditions from that forming a cargo. The inflammable gases evolved from the coal when freshly worked or broken, and which when mixed with air in certain proportions became explosive, necessitated ample ventilation of the bunkers, both before being entered with a naked light and during the whole time they were being worked. A rise in temperature of the coal increased the amount of gas evolved, and, as large coal was less liable to heating than small, the shoots supplying the bunkers should be so arranged that the small coal could not accumulate in any part of the bunkers at which a higher temperature than normal might be expected. In places where high temperatures were to be expected, a thorough damping of the coal would assist in preventing danger of spontaneous ignition. Limbers in bunkers required special attention to ensure that they were tight.

In opening the discussion which followed, Mr. J. Shanks commented on the value of the paper in view of the small amount of reliable information on the subject available up to the present. There was, he said, a general impression that the presence of moisture in the coal was favourably spontaneous, a belief supported by the Royal Commission of 1876, but which had been proved to be unfounded. He considered that holds might be hermetically sealed and inert gases injected as a preventive. It was evident that a probable cause of spontaneous combustion was the breakage of the coal under the hatches during shipment. He cited instances where a tendency to spontaneous combustion had been checked by insulation of the bulkhead in close proximity to the boilers. Mr. R. Balfour considered that the crux of the matter was contained in the results of M. Fayol's experiments, which proved that the prime essential cause of spontaneous heating and combustion of coal was the absorption of oxygen from the air by the coal, and that the conditions most favouring the heating of any coal were a mixture of pieces and powder, a high temperature, a large mass, and a certain quantity of air. He referred to the damage done to ceilings and hatches, which accounted in some degree for the introduction of oxygen, and he emphasized the necessity of ensuring that the limber hatches were perfectly tight. Mr. G. Shearer said he had always found it to be of advantage to damp the coal in the working bunkers. He had found from experience that it was generally at the bunkers nearest the boilers where the tendency to spontaneous combustion was greatest. Mr. W. McLaren considered that surface ventilation and weather conditions had a decided effect upon spontaneous combustion. He did not agree that the practice of wetting the coal was a good one. Mr. J. T. Milton pointed out that the chief value of the paper lay in the fact that it contained a large amount of information which had been obtained with great difficulty, and from sources which were now almost inaccessible. Of particular value was the record of experiments by M. Fayol, who, among other things, had disproved the theory of Dr. Richters that the amount of oxygen absorbed was proportionate to the amount of hydrogen in the coal, by showing that anthracite, which had practically no hydrogen, absorbed a considerable amount of oxygen. M. Fayol had also shown that all classes of coal were liable to spontaneous ignition. Many people were still under the impression that wet coal was dangerous, but this was not the case.

THE CUTTING AND GENERATION OF GEAR TEETH BY MODERN GEAR-CUTTING MACHINERY.*

BY VINCENT GARTSIDE.

(*Continued from page 98.*)

SPUR GEAR HOBBING.

THE cutting of spur gears by means of hobs is what we might consider one of the latest methods, although the idea can be traced back for quite 50 years. In order to understand the principle on which a spur gear hobbing machine works it will be as well to consider the action which takes place. We are all familiar with the old type of worm wheel with the teeth in the wheel cut at an angle with the axis to suit the helix angle of the worm, so that the worm will work at right angles to the axis of the wheel. Now, instead of cutting the teeth at an angle, if we cut them straight across and then lay our worm in the teeth, it will be found that the worm axis is out of square by the amount of helix angle, but if they are mounted up in this position the worm will still drive the wheel correctly. If you imagine a worm and wheel mounted up and working in this manner, and then an extra movement being given to the worm in the form of a traverse across the face of the wheel you have the whole principle of the action of a hobbing machine when cutting a wheel. It is only necessary to make the worm thread in the form of teeth, so that they will cut their way in the wheel while traversing across the face, and spur teeth are generated. A point which must be considered, however, is that in order to make the worm lie in the straight cut teeth correctly, the normal and not the axial pitch of the worm must be the same as the circular pitch of the wheel, and the same remarks apply to the hobs.

The action of a worm running in a wheel is the same as a rack running into a wheel, therefore the principle on which a hobbing machine works is the same as generating from a rack. Now at a glance it would appear that a hobbed gear would be a perfect gear with regard to the tooth forms, but this would only be the case if the hob had an infinite number of teeth. Owing to the thread of the hob having to be made into teeth so as to cut, the spiral is broken up, and the generating takes place intermittently only when the tooth face and hob axis are in the plane of the portion of the wheel being cut. Between each tooth coming into this position the wheel makes a portion of a revolution, with the result that the tooth forms are made up of a series of flats. The number of flats are dependent on the number of teeth in the hob. The accuracy of the tooth form is also dependent on this, so that it is advisable to make the hobs with as many teeth as possible.

This could be improved by increasing the diameter of the hob, but is not advisable, because by doing this it would be necessary to run the hob slower. Now as the feed across the face of the wheel is put on each revolution, it will be obvious that by slowing down the hob you will, therefore, reduce the revolutions of the work, and consequently reduce the amount of feed in a given period of time, thus retarding the output of the machine, because it is not advisable to force the cut, otherwise there is danger of spoiling the hob.

In designing the hobs these points have to be considered, and the best medium taken. These practical difficulties limit the use of hobs for pitches up to about 3in. Above this pitch, in order to make a hob with a suitable number of teeth, the diameter would be such that the price would be altogether prohibitive, irrespective of the difficulties in the manufacture.

Even in the sizes which are in use at present, several attempts have been made to produce a commercial hob with inserted blades in order to reduce the cost, and enable the teeth to be replaced instead of having to purchase a new hob, and secondly, with the idea of grinding the teeth to correct form and pitch, in order to produce more accurate work. With regard to the inserted blade hob, the author has not yet seen a satisfactory one which can be had at a reasonable price, and with regard to the grinding the author cannot see any great advantage, as the flats will always be produced, and it is questionable whether they would not be more accurately produced, and consequently be more obvious to the unskilled eye.

If you desire to produce the very finest class of gear the above points cannot be ignored, but for ordinary gears, even in high-class machine tools, hobbing has proved quite suitable. The continuous action is a particularly good feature, as the gears produced are very regular in pitch all round the wheel. The hobs themselves last a considerable time, are easy to sharpen and keep in order, particularly where a special machine is used for the purpose, and they keep their shape after repeated grindings, and have a large amount of wear in them owing to the number of teeth over which the work is distributed.

Now with regard to the profile of hob teeth. This is taken on a normal section and not in the axial section of the hob, and if the hob is laid in a rack, which of course is an infinitely large gear, the hob thread ought to exactly fill the rack. Now owing to the modification in the rack teeth, as shown in Fig. 8 (see p. 60 ante), it will be seen that the roots of the hob teeth must be rounded in, in order that when cutting the largest gears the points of the teeth shall be rounded off, not to interfere with the flanks of the pinions. When using a hob of this shape for cutting pinions, however, owing to the hob teeth not being rounded off at the points, exactly the same interference takes place between the hob teeth and the pinion

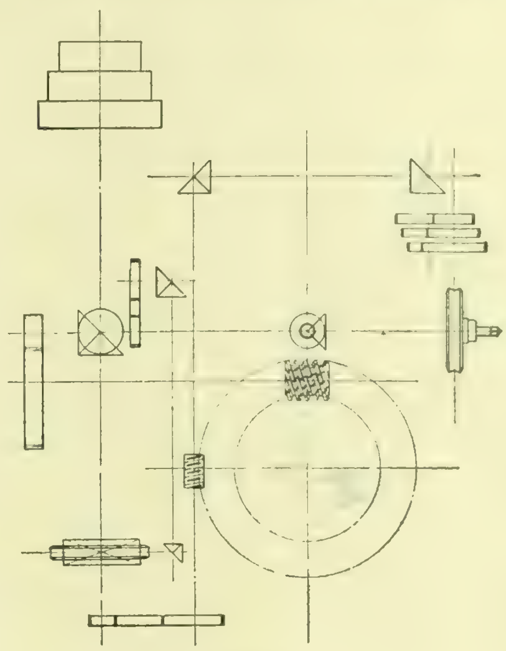


FIG. 24.

flanks, and excessive undercutting results. The teeth of the rack and large wheels are rounded off to avoid this undercutting. It appears to the author that a different hob with the points rounded off ought to be used for wheels where this interference occurs.

All the modifying and compromising is owing to the particular standard in use, viz., the 15° pressure angle and long teeth. By shortening the teeth and increasing the pressure angle, all these interferences are done away with, and a straight-sided rack is only necessary and no modifications. This is the chief advantage of the proposed stub tooth system.

Now with regard to the machines for use with hobs. The general design and arrangements are much the same as the disc cutter machines, in fact the machines for cutting spur gears only are really simpler machines, because there is no automatic intermittent dividing mechanism required, but for the ordinary type of hob the head has to swivel in order to tilt the hob to the required angle. The diagram, Fig. 24, shows connections required between the hob and the work and the movements required.

In hobbing machines the table drive is of the utmost importance, and as it is continuous in its action, and also does the driving of the wheel as well as the dividing, it is generally constructed of a much heavier pitch than is usual on disc cutter machines. Special arrangements are also provided for taking up any wear that takes place on the dividing wheel. The author has designed several arrangements to get over this, and the best arrangement has proved to be two worms at right angles, one of them having axial adjustment to take up for wear. An advantage of this arrangement is that the driving

* Paper read before the Manchester Association of Engineers, January 11th, 1913.

worm is placed directly under the hob. This somewhat eliminates any effect through a slack or worn central spindle.

In order to do away with the complication connected with the swivelling head on spur gear hobbing machines, the author made a hob to cut the gears without having to tilt it to any angle. The most difficult thing to do was to get the correct shape of thread, but this was obtained eventually by shaping a dummy which was fed past the tool at the correct pitch. The thread produced was thinner than standard, and was really the shape produced by thinning the worm thread until it exactly filled the profile of the rack teeth when laid in the rack with its axis parallel with the rack. In other words, it should appear to fill when looking through towards the light. The result was quite satisfactory, in fact Fig. 25 shows a machine which is working quite successfully with this type of hob, and which was designed to use this type only when cutting spur gears. Owing to the peculiar action when cutting, the teeth seem to have a kind of shearing cut, which appears to reduce the effect of the flats produced by tilted hobs.

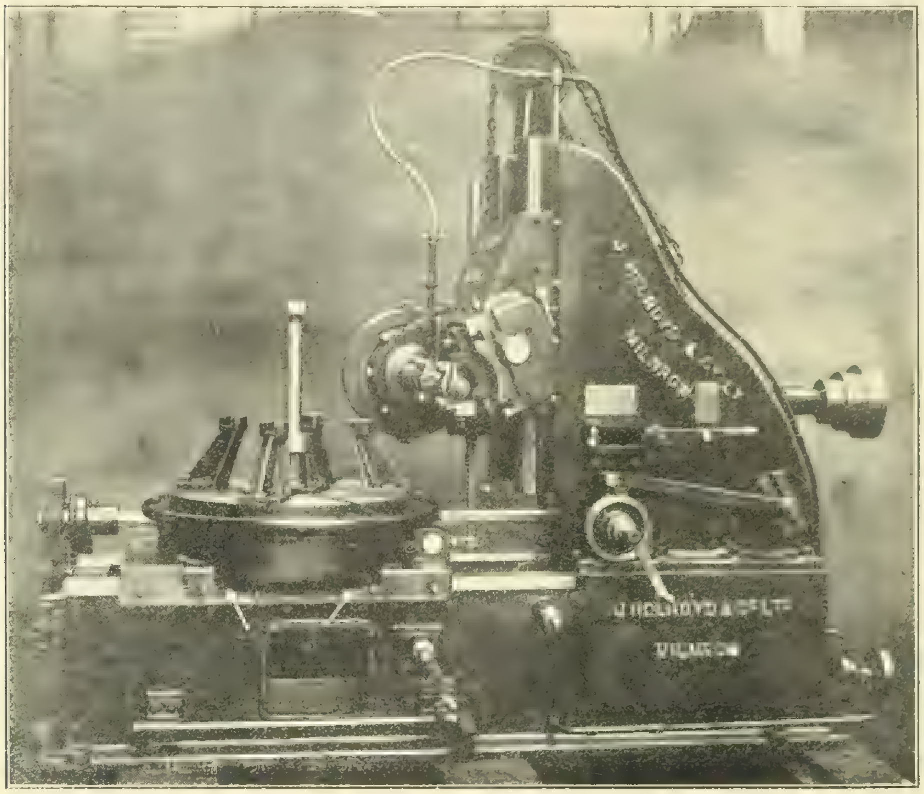


FIG. 25

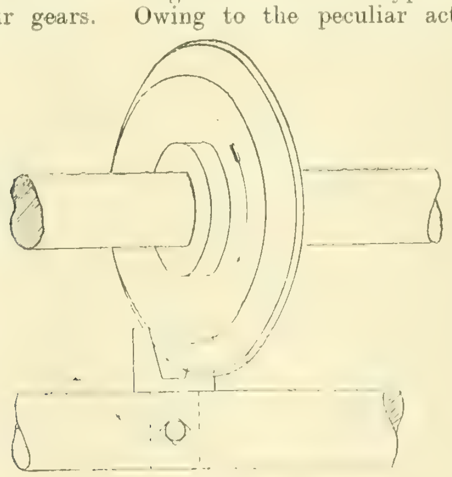


FIG. 27

WORMS AND WORM WHEELS.

In dealing with this type of gearing, only the modern type with the hollow face worm wheel will be considered. The principle used in the cutting of worms and wheels will be readily understood if it is borne in mind that a section taken through the axis of the worm in the plane of the wheel is exactly the same as a rack gearing into a wheel, as Fig. 26, and that the sectional shape of the worm wheel teeth on this plane is the same as a spur gear, only the worm threads have generally straight sides, corresponding with the straight-sided rack, which causes interference and undercutting on the small numbers of teeth. The difficulty, however, which presents itself in the manufacture of worms and worm wheels is that all the shapes of cutters and tools have to be obtained on the normal section of thread of the worm, and in many cases to get these shapes by laying out is a difficult geometrical problem, particularly to the unexperienced person.

The most modern method of cutting the worms is by milling, but this has its limits; in fact, it is sometimes necessary to rough out by milling and finish in the lathe, which happens where the angle of the thread with the axis is great, and where the cutter interferes with the tops of the threads as it leaves the work. In order to get over this lathe finishing, the common practice to-day is to increase the pressure angle, which gives wider spaces at the top of the threads. In the production of the highest class of gears it is usual to mill out the threads to within a few thousandths of correct thickness, and finish by grinding the threads after hardening.

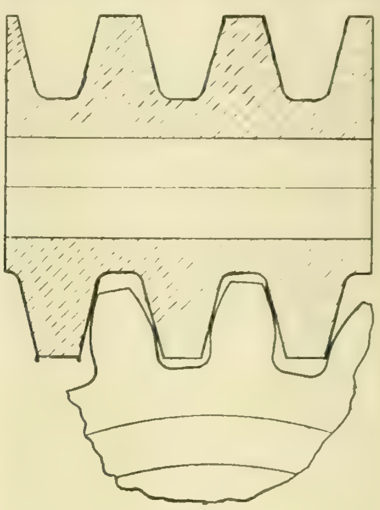


FIG. 26.

In the milling of worms the most important thing is to get the cutter of correct shape. For ordinary single threads it is generally sufficient to make the cutter the same included angle as a rack tooth space, and make it the normal thickness, worked out from the angle of the thread with the axis of the worm; but for long leads and multiple threads this is not good enough, and the shape has to be accurately obtained, and the best method to get this is to generate this form in the following manner.

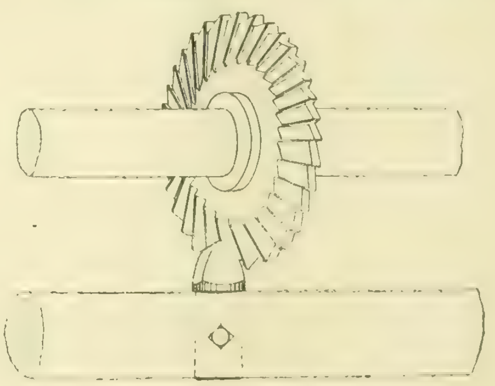


FIG. 28.

Either a worm milling machine, worm grinding machine, or in some cases a universal milling machine is used for the operation. The machine is set up exactly as for milling the worm, but on the cutter mandrel is placed a blank of hard

wood, brass, or white metal. In the place of the worm is placed a mandrel, with a tool got up to the exact axial section of the worm thread, which is the same as a rack tooth space (see Fig. 27). The machine is then started up, and as the blank revolves the tool is fed past the blank at the same spiral as the worm; in doing so it cuts the blank and generates the correct shape to which the cutter has to be made to produce a thread on the worm, which will have the same axial section as the tool. After generating in this manner a gauge is generally made to the shape and the cutter made to the gauge. If the cutter is a standard one for manufacturing

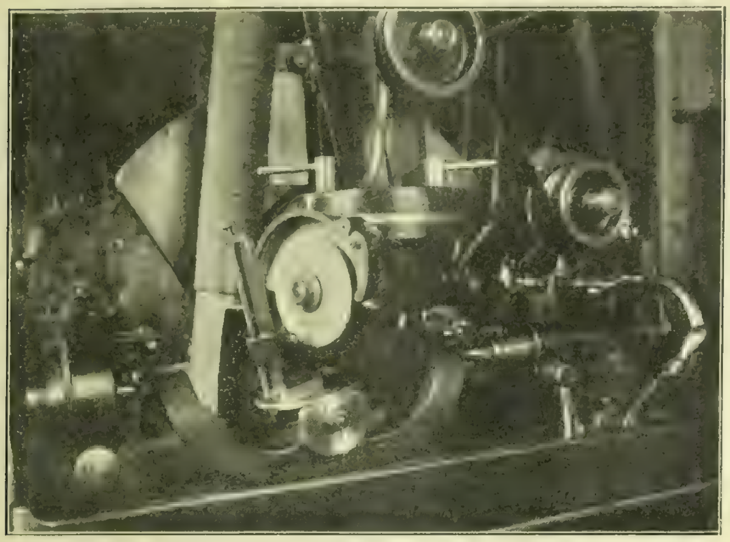


FIG. 29.

large numbers of worms, a master tool can be made, and relieved cutters made as often as required, similar to the ordinary type of spur gear cutters.

One drawback to the use of relieved cutters for worm milling is that they do not cut so freely as an ordinary type of cutter with saw teeth, but the difficulty with the latter type of cutter is that they are not so suitable for the curved profiles required for the long leads owing to the difficulty of sharpening and retaining their form. The author, however, has cut worms with the nearest straight-sided cutter to the slightly curved theoretical shape, and generated the tool for cutting the worm wheel by milling this tool, as shown in Fig. 28, thus putting the curve on the tool for the worm wheel or the teeth of the hobs. This method has given excellent results, but the axial section of the worm is not exactly standard.

With regard to the machines for milling worms, there are a large variety now made. They all work on the same principle, which is the same as an ordinary screw cutting lathe, only a cutter is used instead of a tool. Different makers have different designs to arrive at the same result. Some machines traverse the cutter, some traverse the work, some support the work in centres, and others in stays; all these are points which have to be considered in the selection of a machine. The most important point, however, is the drive to the cutter, and the gearing for this should be as strong as possible. It is preferable where possible to have a large driving gear on the cutter spindle. This can only be done where short worms are cut.

A special machine has been designed for cutting all kinds of worms up to about 6in. diam. by 1½in. pitch. The cutter spindle on the machine has a large internal driving wheel, which enables the 1½in. pitch worms to be cut out of the solid at one cut. The machine is also supplied with a special head, arranged so that the large wheel can be removed and the drive take place through a pinion, so that worms solid with long shafts will clear. These machines are specially designed for cutting the steering worms and back axle driving worms for motor-cars, &c. Another machine, similar to the last but larger, deals with worms up to 12in. diam., 3in. pitch.

With regard to the grinding of worms, this is now becoming common practice, in order to rectify the worms after they are hardened, and a special machine has been designed by the author for this purpose. The operation of the machine is as follows. The worm is carried between centres with a suitable driver, it is given a twisting motion for the lead by suitable change wheels, and for multiple threads an automatic dividing mechanism is provided, with change wheels for the number of starts. The table and work are traversed by belts, and have quick return in either direction, and the dividing can also take place at either end of the stroke to suit the work. The emery wheel is carried on a universal head, which allows the wheel to be adjusted to the different worms to be operated on.

When the machine was first designed for this work it was arranged for grinding the threads by taking successive cuts along the face of the thread, feeding the wheel down at an angle at each stroke of the table, this angle being set according to the pressure angle of the gear. This process produces the most accurate work, and is used for exceptionally accurate gears for experimental purposes. It is not used generally, because it takes much longer than the more general method of grinding the whole depth of face at once.

When grinding by the latter method, however, the same difficulty presents itself as with the milling of the worm, and that is that the shape of the emery wheel has to be made to suit twisted form of thread. An apparatus, Fig. 29, was devised for generating this shape. It is arranged to be mounted between the centres and the machine set up for grinding the worm, the round pillar is tilted over to the pressure angle, and as the apparatus feeds past the wheel spirally, the diamond which is held in a holder which slides on the pillar is fed down at each stroke, the diamond describing a path corresponding with the face of the worm.

The two processes of grinding the worms correspond exactly with the processes used in finishing in a lathe, the first being similar to the finishing by setting the compound rest over to the angle of the thread, and finishing by feeding the tool down the face of the worm thread, and the second being the same as cutting a thread with a vee-shaped tool. In the grinding one side of the thread is operated on at once. The machine is fully automatic in its action, and is also suitable for automatically sharpening hobs, and the emery true-

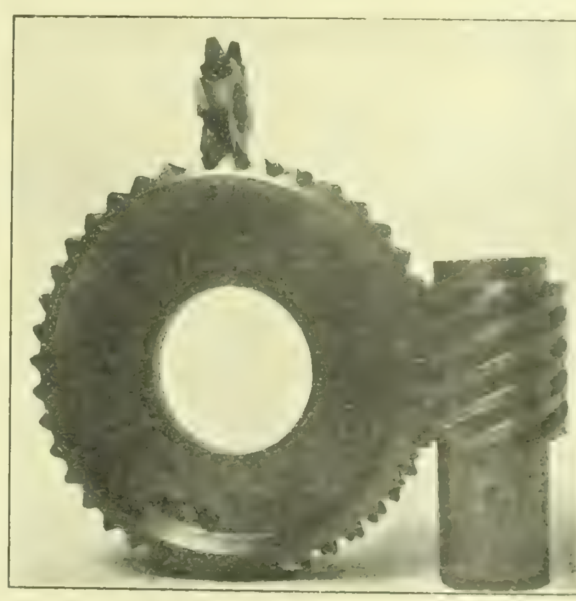


FIG. 30.

ing apparatus is also used for the emery wheels for sharpening quick lead hobs in order to grind a true radial cutting face.

WORM WHEELS.

With regard to cutting worm wheels there are three methods. (1) Cutting with parallel hobs, or the sinking-in process. (2) Cutting with taper hobs with a tangential feed. (3) Cutting with fly cutters with tangential feed.

1. Cutting with Parallel Hobs.—This is the simplest process, and is in most general use for ordinary worm wheels which gear with single and double thread worms, and short

the angle of worm spiral is not very great. In the early days of cut gearing the wheels were generally gashed out first, and then finished by the hob, but now they are cut from the solid by the hob only. The hob thread is similar to the worm thread, the only exception being the difference in diameter to allow for wear and also an amount which is left on the diameter of the hob to cut the clearance between the outside diameter of the worm and the bottom of the spaces in the worm wheel.

2 and 3. **Cutting Worm Wheels with a Taper Hob or Fly Cutter Using Tangential Feed.**—These processes are largely used for cutting wheels to gear with worms of large spiral angles

Fig. 31

and generally with multiple threads. As in the simpler process (1) the shape of the hob thread is the same as the worm thread plus the allowance for clearance, but instead of sinking into the wheel the hob mandrel is set at the correct centres in relation to the work mandrel and then the hob is fed tangentially to the wheel, the hob is tapered where it commences cutting and enters the wheel similar to a taper tap, cutting a small depth to commence with and gradually increasing the depth of the teeth until it has fed the whole distance across the wheel. An advantage of this system of cutting is that fly cutters can be used in place of a hob and the shape of the wheel teeth generated correctly.

These fly cutters are cheap to produce and can be easily made to cut wheels of special pitches to gear with special worms, this being a great advantage where experimental worms and wheels have to be cut, such as in the motor trade, and also where a large variety of wheels have to be cut to meet varied requirements. Fly cutters, however, cut slower than a hob, and where the ratio between the worm and wheel is even and the number of starts in the worm large, it is necessary to cut through each set of teeth separately; this means, going across the wheel two, three, or four times, according to the number of starts in the worm and necessitates the dividing round of the wheel each time, by putting in a hunting tooth, when one pass across the wheel finishes it.

Fig. 30 shows a special hob which the author had made to cut a number of wheels to gear with six start worms and which is really equal to six fly cutters. In order to ensure the shape of tooth being correct it was milled out by the same cutter as the worm and at the same setting and was then gashed and relieved up to a margin on the cutting face of the teeth, it cut very quickly and gave excellent results.

A difficulty experienced with the cutting of worm wheels is to get the worm to be exactly square in the wheel owing to the allowance on the diameter of the hob for wear. In order to overcome this the author has tilted the hob slightly to allow for the difference in angle owing to the larger hob diameter, with satisfactory results, gradually reducing the angle as the hob was reduced in diameter by sharpening.

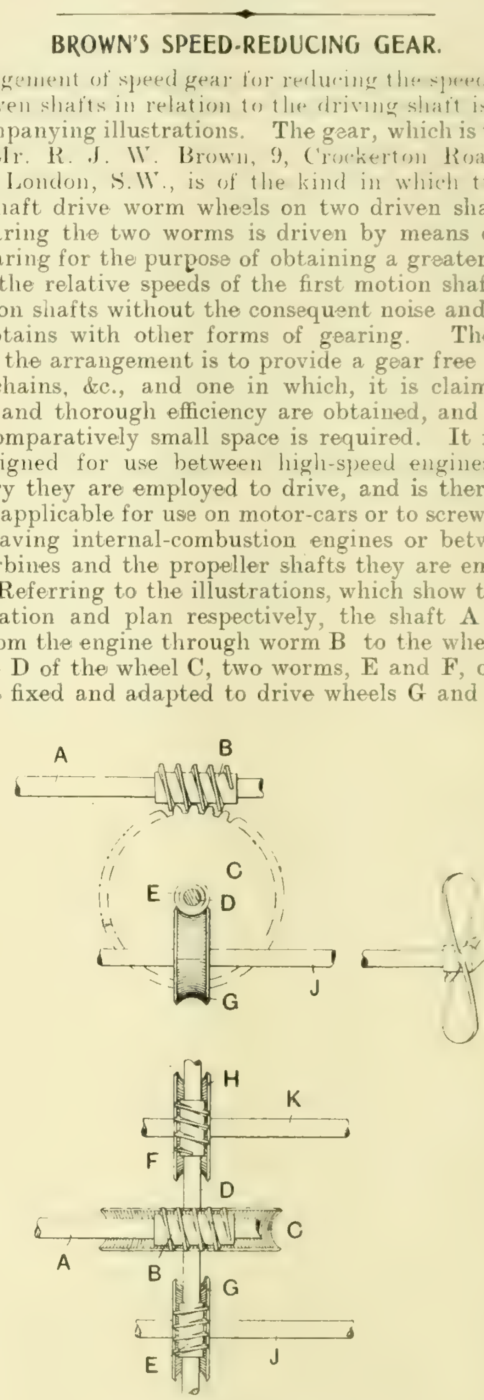
Another method and one which has proved very satisfactory is to make a hob, as Fig. 31, viz., the tapered portion is made similar to an ordinary tapered hob, but following this is a hob which was very carefully made with the shape of the thread exactly the same as the worm thread and of exactly the same diameter. This portion of the hob having very little relief and only sharpened very seldom, the front tapered portion roughs out the wheel and is the portion which is sharpened often, the follower portion being used for finishing or sizing, and owing to most of the work being done by the front portion the follower keeps up to size for a very long time.

A large machine has been designed to cut wheels up to 6ft. diam. and 5in. pitch, by either hobs or fly cutters. The ratio between the cutter and work is governed by suitable change gears, but an extra set of change wheels is provided, which through a differential gear train gives an added on motion to the wheel to suit the pitch or lead as the tool is being fed tangentially to the wheel. The feed in this machine is entirely independent, being put on by means of a silent ratchet at every revolution of the work.

(To be continued.)

BROWN'S SPEED-REDUCING GEAR.

An arrangement of speed gear for reducing the speed of two or more driven shafts in relation to the driving shaft is shown in the accompanying illustrations. The gear, which is the invention of Mr. R. J. W. Brown, 9, Crockerton Road, Upper Tooting, London, S.W., is of the kind in which two worms on one shaft drive worm wheels on two driven shafts. The shaft bearing the two worms is driven by means of further worm gearing for the purpose of obtaining a greater disparity between the relative speeds of the first motion shaft and the last motion shafts without the consequent noise and vibration which obtains with other forms of gearing. The primary object of the arrangement is to provide a gear free from spur wheels, chains, &c., and one in which, it is claimed, great strength and thorough efficiency are obtained, and for which only a comparatively small space is required. It is particularly designed for use between high-speed engines and the machinery they are employed to drive, and is therefore particularly applicable for use on motor-cars or to screw-propelled vessels having internal-combustion engines or between high-speed turbines and the propeller shafts they are employed to drive. Referring to the illustrations, which show the gear in side elevation and plan respectively, the shaft A transmits power from the engine through worm B to the wheel C. On the shaft D of the wheel C, two worms, E and F, of opposite hand are fixed and adapted to drive wheels G and H respec-



Brown's Speed Reducing Gear.

tively, these wheels being keyed to the propeller shafts J K. It will be obvious that the gear is in constant mesh and that by altering the ratio of the worms and wheels a variation in speed of shaft A in relation to shafts J and K can be obtained. The whole of the gear can be run in an enclosed oil bath of simple construction, and one shaft could have a plurality of worms adapted to drive different wheels on the same or different shafts, and by sliding or clutching the worms and wheels a variation in speed is obtainable.

CONDENSER DESIGN.

IN the discussion on Mr. William Weir's paper on "Auxiliary Units Between Exhaust Pipe and Boiler," read before the Institution of Engineers and Shipbuilders in Scotland, Mr. D. B. Morison contributed some interesting information relating to condenser design, which we reproduced in our issue of December 27th last (see p. 802, Vol. XXX.). The consideration of Mr. Weir's paper was concluded at the meeting of the Institution on the 14th inst., and we now reproduce that part of Mr. Weir's comprehensive reply which dealt with Mr. Morison's contribution :—

With regard to the question of surface condenser design I

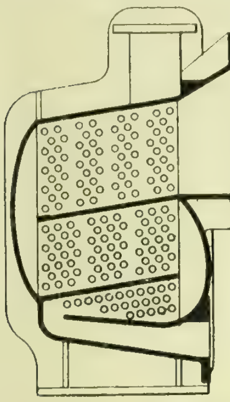


FIG. 1.—CONTRAFLO CONDENSER TESTED BY PROF. WEIGHTON IN 1906.

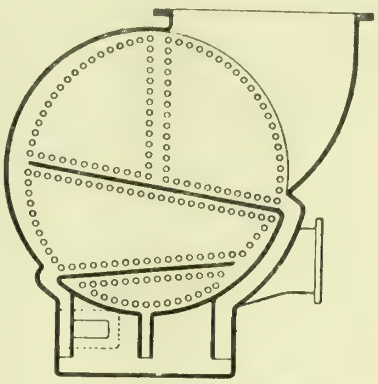


FIG. 2. CIRCULAR CONTRAFLO CONDENSER, 1906.

am in agreement with one of the speakers that an amount of intangible discussion has grown up around the subject recently, and to comparatively unimportant issues there has been devoted an amount of attention which might with advantage have been applied elsewhere ; my apology for adding to the literature on the subject is a sincere desire to clarify the position, and to apply the touchstone of actual practice as a corrective to theories and assumptions more or less academic and unrelated to natural conditions.

Mr. D. B. Morison prefaced his remarks by a statement that it would be of greater technical service to relate his experiences in surface condenser design rather than to criticise my references to the subject. My references to surface condenser design differ from those in almost all other papers on this subject in their brevity, as I give in very concise form all the essentials of correct design within the limit of my experience. I then follow this by giving a large number of examples of actual condenser practice based on these essentials, together with the actual performances of the condensers. To render his remarks of real technical service, it is obvious that Mr. Morison should point out wherein the described practice is wrong, or if my statements of the essentials of design are wrong, he should correct them. As he has not done so, I am put in the position of requiring to criticise what constitutes practically a paper by Mr. Morison on condenser phenomena. As his remarks are not arranged systematically to lead to a definite conclusion, I am compelled to deal with them in their unrelated sequence.

In the first place, he lays great stress on the importance and value of Prof. Weighton's paper of 1906, and claims that that paper definitely established the correctness of certain principles. While I have no desire to depreciate the cost and elaboration of Prof. Weighton's research, I totally disagree with Mr. Morison as to its value, and especially as to its effect on present-day design. The paper in question dealt with the comparative performances of two condensers, one an old fashioned rectangular condenser of small actual size, not representative of practice at that date, and the second a condenser with certain special features of design. The trials showed that the new condenser gave a better performance than the old one. Prof. Weighton and Mr. Morison attributed the improvement to: (1) Compartmental drainage of the feed water, so that the surfaces in the lower compartments are not impeded in their condensing action, the importance of this feature being apparent, and its influence being seen on the results. (2) Abolition of the steam space, and the substitution of a passage of such shape and section as will secure the distribution of the steam over the whole length of the tubes. (3) Tubeless passages connecting the compartments.

Prof. Weighton stated in this paper in at least four different instances that the augmented efficiency of the surface was due to the early interception and removal of the feed water. He also said that the higher hot well temperature and the smaller amount of condensing water and surface were both due to the same cause—the compartment drainage of the condenser.

In Mr. Morison's discussion on this paper he stated that the novel features of the apparatus consisted of sectional drainage, maintenance of parallel steam lines of flow, and alteration of direction of flow in tubeless passages. He also stated that there was no novel feature on the water side, as the water flowed through the nests of tubes in series at speeds adopted in modern practice. I took the opportunity in the discussion on this paper of stating my disbelief in sectional drainage. With reference to the feature concerning the steam flow over the surface, I would refer you to my paper, where you will find the first enunciation regarding surface condenser design expressed as follows: "In an efficient surface condenser the steam should take such a course that it will flow over all the tubes, and at a uniform velocity, and no spaces should be left which permit of short-circuiting." This feature is essential in design, and is referred to by Mr. Morison as contained in his patent of 1904, and in the design of the first "Contraflo" condenser he "starts off," as he puts it, by fulfilling this requirement.

The full and correct value of Prof. Weighton's paper can be measured by the extent to which the alleged improvements have become embodied in modern designs. In the last four years I have personally been associated with the design of condensers for about 9,000,000 h.p., embracing the most important examples in marine practice, and in not a single case are the condensers divided into compartments, nor are they sectionally drained ; they have all more or less a steam space, and none of them have tubeless passages.

Further, Mr. Morison, in his own recent practice, does not appear to embody these particular features to any extent, and I would refer you to the diagrams, Figs. 1 to 5, showing the development of design of "Contraflo" condensers since 1906. These illustrations are taken from Mr. Morison's published papers on the subject, and they serve to show the gradual lack of adherence to the principles which, he claims, Prof. Weighton established, and clearly demonstrate how the feature of sectional drainage dominated the earlier designs. It accordingly only remains for me to point out the factor which was mainly responsible for the better performance of the 1906 condensers, particularly as it was a factor barely

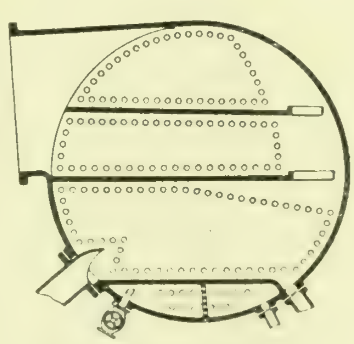


FIG. 3.—CIRCULAR CONTRAFLO CONDENSER, 1908.

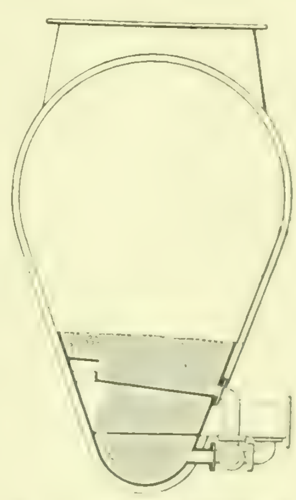


FIG. [illegible]—CONTRAFLO CONDENSER, [illegible]

mentioned either in the paper or in the discussion ; it certainly was not emphasized. This factor was undoubtedly the increase in velocity of flow of the circulating water through the tubes.

With reference to Mr. Morison's remark regarding the provision for dealing with large quantities of air leakage, resulting from accidental leakage into the system, I would simply say that I have no experience of accidental leakage which a normal air pump could not handle satisfactorily enough under the circumstances until the accident was repaired ; and I think it quite unnecessary to provide air

pumps to maintain the highest degrees of vacua under other accidental conditions.

We now come to the most important part of Mr. Morison's remarks, wherein he states: "In practice the crucial problem in the attainment of high vacua was how best to treat the small quantity of air which normally entered the condenser with the steam"; and he submits a theory whereby a solution might be found along the simple lines of elementary first principles. Now careful observation of phenomena is generally more helpful than theory in offering solutions of problems. Mr. Morison's theory occupies much space. I will venture to offer a solution of the problem in a very few words. The best way to treat a quantity of air in a condenser to attain high vacua is to fit an air pump to the condenser capable of

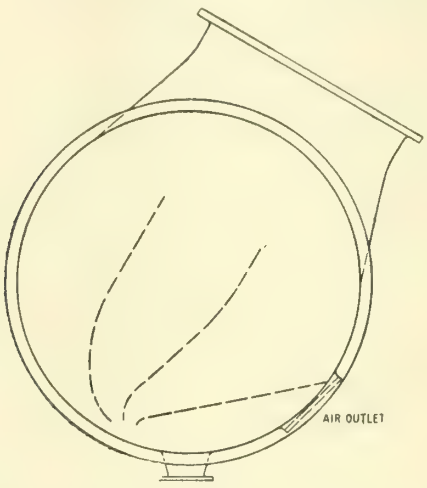


FIG. 5.—CIRCULAR CONTRAFLO CONDENSER, 1912.

removing the air, and I am afraid difficulty will be found in obtaining any other solution of the problem.

Dealing now, however, with the theory and its basis, Mr. Morison says Mr. J. A. Smith carried out experiments to determine the effect of air on the heat transmission through a condenser tube, and certain results are quoted from these experiments. I cannot emphasize too strongly that any theory or practice based or affected by these experiments will be absolutely valueless, while, generally speaking, the results have no bearing whatever on surface condenser design or practice. Mr. Morison himself confirms the unfortunate effect of these fallacious results when he states that a film of air of minute thickness has a degrading effect on the heat transmission of a condenser tube. Now, in the first place, there are no films of air, nor are there any films of steam, in a condenser. There is a mixture of air and steam or air and aqueous vapour, each occupying the whole space. Next, it will be recollected that one of my essentials of design was that the steam path must be such as to maintain the velocity of steam flow, and this is a most important factor. The relative weights of steam and air play no appreciable part in these condenser phenomena. In Mr. Smith's experiments the steam conditions were practically static, and accordingly have no direct connection with condenser phenomena, and the basis flaw of Mr. Morison's theory, and his conclusion, is that he always considers a condenser in a static condition rather than in a working condition.

The effect of air in a working surface condenser is not in any way due to a resistance imposed on heat transmission by its presence and through being a poor heat conductor, but solely and simply to the physical conditions of temperature and pressure caused by its admixture with aqueous vapour. I totally disagree with Mr. Morison's illustrative hypothetical diagrams showing air distribution, and only fear that these may lead to further misconception of the real conditions. In a working condenser the phenomenon consists of a mass of cooling surface working at high transmission rates, with a more or less clearly defined air zone, wherein the total transmission per square foot (not per degree difference per square foot) is impaired, due to the physical conditions of temperature and pressure. Accordingly, if the essential condition of uniform steam flow be maintained in a condenser design, the contour of the condenser becomes a wedge, and having obtained that all else is dependent on the air pump, assuming fixed circulating water conditions. The function of the air pump is to reduce the air zone level, and to allow the working part of the condenser to extend itself, and only the air pump can perform this function.

Mr. Morison's remarks regarding eddies and means of preventing air particles making multiple appearances in any one plane can hardly be accepted as serious when the actual velocities are remembered. To understand an air particle "lingering" in a modern condenser with uniform steam flow is an effort of imagination of which I am incapable. The worst eddies in a condenser are those caused by the tubes. Any other eddy troubles are caused by the presence of baffle plates or deflectors.

Having now by means of his theory obtained the highest attainable vacua, Mr. Morison goes on to consider its value, and therein raises an interesting question, and at the same time falls into an unfortunate error. I have already been subjected to a considerable amount of criticism by Mr. Morison for pointing out that in reciprocating marine installations the highest attainable vacuum is not synonymous with overall economy. Sir Charles Parsons in the early days of the turbine published a diagram showing the effect of vacua on the steam consumption of the turbine, and this diagram is practically reproduced by Mr. Morison in Fig. 5.* This diagram is probably literally correct, but it is used and applied, and inferences drawn from it, in a dangerous and misleading manner. In the first place, I will not consider the part of the diagram below 27in., as lower degrees of vacua need not be considered in association with turbines. I look on the introduction of these into the diagram as perhaps impressive to the uninitiated, but of no practical value. The diagram shows, therefore, the effect of a drop of 2in. in vacuum, from 29in., on the steam consumption of the main turbine. Mr. Morison then applies this commercially, but taking a power station, for example, money is not expended on the direct purchase of steam; it is coal which is purchased. Now the diagram does not show the effect of the vacuum drop on the only item which matters—the coal. The correction for the hot-well temperature and the reduced cost for circulating water for the 2in. in question is a very important and vital matter, but it is completely ignored by Mr. Morison. As the effect of these factors varies according to the type of installation I have prepared a diagram (Fig. 6) showing the necessary correction for two conditions, the first being a power station condition, with 55° inlet water and electrically-driven circulating pumps; the second condition being a British warship with steam-driven circulating pumps, wherein the exhaust is led to the low-pressure turbine, and not to the feed water. As will be seen from the diagram, Mr. Morison's figures, in the sense in which he asks them to be applied, are wrong to the extent of 35 per cent. in one case and 65 per cent. in the other case.

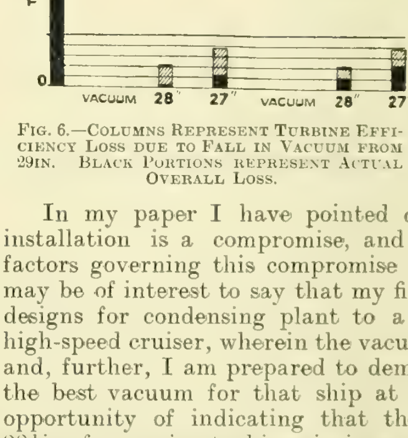


FIG. 6.—COLUMNS REPRESENT TURBINE EFFICIENCY LOSS DUE TO FALL IN VACUUM FROM 29IN. BLACK PORTIONS REPRESENT ACTUAL OVERALL LOSS.

Mr. Morison's statement that the highest attainable vacuum is represented on a warship by increased military efficiency, and is of supreme importance, is a pure assumption, and when he has more experience of warship machinery problems he will then find that it is an ill-considered assumption.

In my paper I have pointed out that every condenser installation is a compromise, and in warship practice the factors governing this compromise are especially varied. It may be of interest to say that my firm have recently supplied designs for condensing plant to a foreign navy for a very high-speed cruiser, wherein the vacuum at full power is 27¼in., and, further, I am prepared to demonstrate that that will be the best vacuum for that ship at full power. I take this opportunity of indicating that the value of vacuum over 28½in. for marine turbines is, in my opinion, becoming under many conditions open to question. Almost everything in

* See "The Mechanical Engineer," December 27th, 1912, page 803.

engineering is a compromise, and while, on the one hand, you may have a fair percentage of improvement in the steam consumption, on the other hand, you have to consider the increased circulating pump consumption, the increased weight and space for air and circulating pumps, the increased weight and space of the main condensers, the effect of reduced hot-well temperature, and the increased weight and space of the low-pressure turbines to satisfactorily utilise the high vacuum, so that in the end we may come, perhaps, to regard even for turbines a practical limit in the reduction of back pressure as desirable.

LIQUID FUEL.

THE first of three Cantor lectures on liquid fuel, by Prof. Vivian B. Lewes, was recently delivered before the Royal Society of Arts. He stated that by "liquid fuel" was meant liquids which by their combination with the oxygen of the air generated energy in such a form as to be easily utilised. For such liquids to have commercial value they must be sufficiently plentiful to enable them to compete with solid fuel, both in distribution and price. All kinds of fuel consisted of bodies formed by the absorption and rendering latent of energy during processes of vegetable or, more rarely, animal life. Originally the energy was derived directly or indirectly from the sun, and when by the processes of combustion the bodies were again resolved into the carbon dioxide and water vapour from which they were formed, the energy latent within them for perhaps geological ages reappeared as the sensible heat that was utilised for domestic comfort and conversion into the other form of energy employed for light and power.

A number of theories were put forward as to the formation of oil, and the one most favoured by the theoretical chemist was that it was the product of the action of steam at high temperatures on metallic carbides taking place probably at great depths, and that the hydrocarbon gases and oil had then found their way into and collected in the strata in which the oil was now found. It had also been suggested that petroleum was produced by the heating of already-formed deposits of shale, lignite, or coal by the intrusion of igneous rocks; but in the oil-bearing measures themselves signs of such volcanic action were rarely to be found. All the evidence went to prove that the oil was of organic origin, and many observers had ascribed it to the checked decomposition over long periods of animal remains from the low forms of fish life. There were several points in favour of this view, as undoubtedly brine and salt deposits were nearly always found in the oilfields, and in most cases with the oil itself, while fossilised deposits pointed to a marine origin, and the work of Engler and Hofer showed that oil could be produced from such forms of animal matter. Practical considerations, however, made it clear that, even taking into account the differences between the atmospheric conditions then and now, which would affect not only terrestrial but also marine growth, it was impossible to ascribe the origin of the vast quantities of petroleum occurring in nature to any such source, although it was not only possible but extremely probable that some portions of certain oil supplies had been formed in this way.

He had always held the view that the real source from which the main bulk of oil had been derived was marine vegetation, which under the conditions existing in those early days probably grew in shallow seas in far greater quantities than at the present day. He was well aware that some authorities of wide experience were opposed to this view and held it up to scorn, but all he had seen pointed to this being the real source from which the chief bulk of oil was formed. The utilisation of seaweed for the production of various commercial commodities led to a good deal of work being done upon it during the last century, and researches made by Mr. E. C. Stanford showed that when any kind of seaweed was submitted to destructive distillation at a low red heat large volumes of gas were evolved and an oily tar was produced, which on redistillation yielded paraffin oil (as he termed it) in considerable quantities. From a ton of weed of the genus fucus, the most common marine growth, it was possible to obtain 6·7 galls. of oil. This theory of the formation of oil from marine growths of the earlier period of the world's history fitted in better with most of the facts observed in the oilfields than any other, but it would be a great mistake to imagine all oil to have been formed from this source, as in special conditions undoubtedly oil was formed from local distillations of carbonaceous material and also from animal remains. It was, however, safe to say that petroleum was a decomposition product of organic matter.

To all intents the substance spoken of as petroleum was a mixture of hydrocarbons having a specific gravity which varied from 0·7 to 1·0, either of which limits was but rarely reached, and capable of being separated by fractional distillation into a number of more simple mixtures. Pennsylvanian petroleum consisted of a mixture of compounds containing many belonging to the saturated or paraffin series, but the oil from the Baku district in Russia contained a large proportion—some observers put it as high as 80 per cent.—of hydrocarbons of different character, known as naphthenes, and isomeric with the ethylenes. Many observers had conjectured that the difference in composition indicated a difference in source; that might be so, but the fact remained that by heating under proper conditions Pennsylvanian oil could be converted into a mixture of naphthenes and other hydrocarbons of much the same composition as the Russian oil, and it seemed more probable that the differences marked different phases of formation rather than different sources, more especially as the two classes of oil might be found in fields not far apart.

The variations between the different crude oils, and still more between the fractions of medium boiling point, were remarkably small considering the variation of the conditions under which they had been formed. This uniformity in composition of the crude oil, and the small variations found in the definite fractions obtained from it by distillation were important factors in its use as liquid fuel, because instead of being obliged to select the source of the supply and character of the material, as was the case with coal, it was known that, given a satisfactory gravity, flash point, viscosity, and sulphur content, fairly uniform results would be obtained, whether an American residuum or a Russian astatki was being dealt with.

It was now recognised that very few countries existed in which small quantities of petroleum were not to be found. Even England was fluttered during the past year by a deep boring near Newark yielding some few gallons, while traces had been found as near London as Willesden. But it by no means followed that there existed many fields of the prolific character of the Baku or Pennsylvanian districts, which during some 40 years yielded the bulk of the world's supply, and which were now pointing the moral that an oilfield, however prolific, was only a natural storage tank for a long-dead manufacture, and that the more fields were developed and the more petroleum used the nearer was the inevitable end of the supply coming. The world's output of petroleum was now nearing 50,000,000 tons per annum. Last year something like 1,250,000 tons of products were imported into the United Kingdom, 70 per cent. of which came from America, while the Dutch East Indies, Rumania, and Russia in the order named made up the bulk of the remainder. The percentages of the total oil produced were: United States, 63·99 per cent.; Russia, 21·48; Galicia, 3·87; Dutch East Indies, 3·37; Rumania, 2·97; India, 1·87; Mexico, 1·02; Japan, ·59; Peru, ·40; Germany, ·32; Canada, ·10; and other sources, ·02.

Electrical Locomotives. — At a recent meeting of the Scientific Society of the Glasgow Royal Technical College, a paper on electric locomotives for main line and suburban services was read by Mr. B. P. Haigh, of the Engineering Department of the University of Glasgow. Remarking that public interest in the problem of electric railways had mainly been roused by the work of electrical engineers, the author dealt with the mechanical side of the problem rather than the electrical. Several difficult mechanical problems were raised in the design of heavy electrical locomotives, these being mainly due to the great weight of the moving parts. For slow speeds the motors could be geared to the wheels, as was done on tramway vehicles; but for higher speeds it was necessary that the motor should be spring-borne. Rigid attachment of the motor to the driving axles involved risk of derailment, as well as excessive wear of the permanent way, and vibration. Different methods of coupling the axles to the motors were discussed, and slides illustrating recent designs were shown.

BOOK REVIEWS.

A Manual of Marine Engineering. By A. E. Seaton, M.Inst.C.E., M.Inst. Naval Architects, M.Inst.M.E., &c. Seventeenth edition, revised and enlarged. London: Chas. Griffin & Co., Ltd. 9in. by 7in.; 966 pp. Price 28s. net.

Mr. Seaton's work has been so long before the public, and recognised as a standard authority, that it calls for nothing in the way of introduction. During the quarter of a century that has elapsed since it made its first appearance considerable revision has been necessary to keep abreast with current practice. In the last few years the pace in certain directions of marine engineering practice has been, if anything, faster than formerly, and to do justice to the many new phases of it that now present themselves has necessitated in this edition not only great enlargement, but also re-writing a large portion of the work. The introduction of the turbine, the internal combustion engine, and the innumerable applications of electricity, combined with developments in the metallurgy of many of the materials used for constructive purposes, has led, in some directions, to changes that are almost revolutionary. It is impossible in the limited space at our disposal to even epitomise the contents of a volume like this, containing some thousand pages, and having regard to the fact that the general scope of the work is familiar to most people interested in marine engineering, it is perhaps hardly necessary to do so. Suffice it that the work deals fully with practically all the details of power equipment in modern steamships, and sustains the reputation it has so long enjoyed of being one of the leading text books on the subject.

* * *

The Journal of the Institute of Metals. Vol. VIII. Edited by G. Shaw Scott, M.Sc. The Institute of Metals, Caxton House, Westminster, S.W. 21s. net.

The major portion of this issue of the journal consists of papers read at the annual autumn meeting of the Institute in September last, and include "The Structural Resolution of the Pure Copper-Zinc Beta Constituent into Alpha plus Gamma," by Prof. H. C. H. Carpenter, M.A., Ph.D.; "The Annealing of Coinage Alloys," by T. Kirke Rose, D.Sc.; "The Effect of Temperature on Tensile Tests of Copper and its Alloys," by Prof. A. K. Huntington; "Inter-Crystalline Cohesion in Metals," by W. Rosenhain, D.Sc., and D. Ewen, M.Sc.; "The Solidification of Metals from the Liquid State," by G. T. Beilby, LL.D., F.R.S.; "Oxygen in Brass," by Prof. T. Turner, M.Sc.; "The Joining of Metals," by A. E. Tucker, F.I.C.; and "Autogenous Welding," by Prof. Dr. F. Carnevali. In addition, the volume contains a verbatim report of the third May lecture by Sir J. Alfred Ewing, K.C.B., F.R.S., on "The Inner Structure of Simple Metals," as well as a selection by the Editor of interesting abstracts of papers relating to the non-ferrous metals.

* * *

Practical Geometry and Graphics. David Allan Low, Wh.Sc., M.I.Mech.E., Prof. of Engineering, East London College; with 800 illustrations and 700 exercises. London: Longmans, Green, & Co. 8¾in. by 6in.; 448 pp. Price 7s. 6d. net.

This is essentially a book for the student, and though the subject is one on which existing text books supply an ample field for selection, the one under notice presents some features which should commend it to those who are making a choice. The principal one is its comprehensive character. Most text books which deal with this subject treat only of a limited portion, and two or three books would usually be necessary to bring under the eye of the student the matter contained in this work. Prof. Low has had very wide experience as a teacher, and is particularly acquainted with the needs of engineering students, to whom geometry in one form or another is an important part of their training, not only for its many practical applications in problems relating to stresses in structures and accurate presentation of mechanical constructions in the shape of orthographic or perspective plans, elevations, and sections, but also for the excellent mental training which, apart from everything else, co-ordinate or descriptive geometry affords. Not the least of the valuable features of the book is the admirable selection of examples, with illustrated diagrams relating to their solution. The book is divided into some 28 chapters, and, broadly speaking, deals with the plane geometry of the line and circle and conic sections, problems relating to loci, graphic statics and periodic motion, co-ordinate geometry, including the intersections of lines, planes, and solids, isometric and perspective projection, including problems of shadows, and also a useful chapter on questions relating to helices and screws. The work is good in every way, and we doubt not will take a prominent position in the estimation of those interested in this subject.

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Evolution of the Internal-combustion Engine. By Ed. Butler. With 188 illustrations. London: Chas. Griffin & Co., Ltd. 8¾in. by 6in.; 237 pp. Price 8s. 6d. net.

The contents of this book, as the title implies, are mainly historical, and though the development of the internal-combustion engine, as we know it to-day, has taken place almost entirely within the lifetime of a generation still living, it is surprising to find how much there is to say and record. The author's experience gives him excellent qualifications for the task he has undertaken, for in several directions he has aided notably in the progress that has been made, and his love of the subject is manifest by the painstaking way in which details are illustrated and described. All who are interested in the practical working of combustion engines will find this volume interesting and worthy of a place on their bookshelf.

* * *

Machine Design: Hoists, Derricks, Cranes. By H. D. Hess, M.E., Professor of Machine Design, Sibley College, Cornell University; with 318 illustrations. London: Lippincott Company. 9½in. by 6½in.; 368 pp. Price 21s. net.

The contents of this book may be said to consist of the mechanics of the constructional details in the way of belts, gearing, shafting, bearings, hooks and beams, brakes, clutches, &c., with special reference to their employment in hoisting apparatus, and a very brief introductory reference to the properties of constructional materials. The author has an established reputation in America and is well known for his contributions on many engineering problems, and his treatment of the matters herein dealt with is, as we should expect, both sound and practical. The only adverse criticism one is inclined to make with regard to the book, and it applies more or less to nearly all American text books that come under our notice, is in respect to the price. This is certainly stiff, when compared with the information of a more or less similar character available to those who desire it in British text books. Though thick paper, large type, and wide spacing help to make text, formula, and illustrations clear and imposing, American publishers push these features to excess, with the result that one feels that, without any material sacrifice, their text books could be compressed into much smaller dimensions, with advantage in every way.

BOOKS RECEIVED.

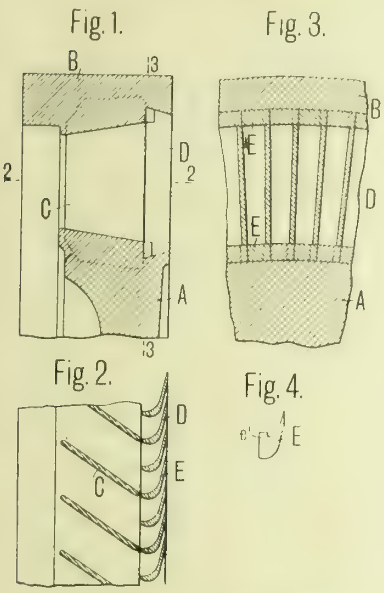
The Manufacture of Iron and Steel. By H. R. Hearson, M.I.Mech.E. London: E. & F. Spon, Ltd. 8½in. by 5¾in.; 100 pp. 4s. 6d. net.

Hygiene for the Worker. New York: American Book Company. 7½in. by 5¼in. 50 cents.

Foundry Pig-iron.—The third meeting of the session in connection with the Birmingham Branch of the British Foundrymen's Association was held on Saturday last, when Mr. W. L. Parker, F.I.C. (Rugby) read a paper entitled "Specifications of Foundry Pig-iron." The question, he said, was essentially a national one. The fracture of pig-iron, he contended, was not a sufficient test as to its properties. Grading by fracture at the blastfurnace was left in the hands of men who had not had sufficient education on the subject. Mr. Parker proceeded to detail his system of grading pig-iron by combining carbon and silicon, and afterwards dealt with the composition of foundry cokes, the gas of cold, semi-cold, and hot blast, the ores used in the blastfurnaces, the refining of pig-iron, and the would-be use of specifications.

STATOR BLADES FOR STEAM TURBINES.

IN respect of the fixing, a difference has hitherto been made between two kinds of steam turbine stator blades, namely, "built in" and "cast in" blades. In the first arrangement the blades, which are made separately, are inserted in corresponding recesses in the stator discs of the turbines. Stator discs of this kind with "built in" blades enable great accuracy to be attained in construction, but are not satisfactory in the case of blades of great length, and when the turbines are worked under full admission do not satisfy the requirements as to strength demanded of the blade rims, and consequently do not permit the length of the blades to be increased as may be desired in turbines worked under full admission. For these cases the casting in of the stator blades is usual. By this method of construction the required strength of the blade rim can, it is true, be obtained, but it has other disadvantages which limit its applicability. First and foremost, the casting in of the blades easily impairs the accuracy and uniformity of the angle of the blades and the distance between them, and owing to shifting of the cores the areas of the blades are easily rendered different. Moreover, the casting in of the blades necessitates, on account of the cores which have to be inserted, a somewhat considerable minimum distance between the several blades, so that when cast in blades are used, it is not possible to make the division between the blades as small as the most effective guiding and utilisation of the steam would require. This difficulty is very considerable in the case of stator blades in particular, because the exit ends of the blades lie very close to each other owing to the small outlet angle. Again, the production of the cores and the moulding thereof must be carried out with scrupulous care, so that this method of construction is both tedious and expensive. Even with the most careful construction the subsequent possibility of the disc being of any use at all, depends on the success of the casting.



STATOR BLADES FOR STEAM TURBINES.

The arrangement illustrated herewith has been designed and patented by Messrs. Krupp Bros., Kiel-Gaarden, Germany, with the object of providing a stator device which shall have the advantages of the known methods of construction without exhibiting their defects. Fig. 1 is an axial section through the stator blade rim of a turbine. Fig. 2 is a developed section on the line 2—2 of Fig. 1, looking in the direction of the periphery of the disc. Fig. 3 is a section on the line 3—3 of Fig. 2, looking from the right, and Fig. 4 is a detail. A is the disc of the stator disc of a steam turbine, and B is the ring which bounds the stator disc on the outside. The stator blade rim proper consists of two separate systems of blades, namely, a blade rim C for the admission of the steam, and a ring of blades D for the outlet of the steam. The blade rim C consists of straight or curved plates which are cast into the stator disc A B. The second blade rim D is connected to the outlet end of the first blade rim C, the divisions between the blades D being smaller than divisions between the blades in the rim C. This second rim is formed by short, sharply curved blades D, which are pushed into a dovetail shaped undercut groove in the stator ring, and are held in position by inserted intermediate pieces E. The stator ring may in this case be divided, or provided with an opening for the introduction of the blades. The intermediate pieces E, the cross-sectional form of which is shown in Fig. 4, have projections e^1 which engage in corresponding recesses in the adjacent blades D. By this means the intermediate pieces themselves are prevented from falling out.

The arrangement has the following advantages. Firstly, the cast in steam inlet blades C favourably influence the strength of the entire rim, even when the blades are of great length and under full admission. These blades may also, as they are mostly straight or only slightly curved, be constructed without making too severe demands on the foundry, and the theoretically correct distribution maintained, whereby good guiding and a favourable action upon the speed of the steam issuing from the adjacent rotor is obtained. The "cast in" straight blades also give greater strength to the stator blade rim in the direction of the axis of the turbine, in comparison with the wholly cast in blades which are curved over almost their entire length, so that, as experience has shown, the blades may be shortened in this direction and a reduction in the width of the stator rings and of the whole turbine thereby obtained. The steam outlet blades D lying alongside the steam inlet blades C and built into the stator, in contradistinction to cast in blades, permit any desired fineness of curvature, and enable absolute accuracy of the form, area, and angle of the blades such as is required for the most favourable utilisation of the steam to be maintained. The number of steam outlet blades is entirely independent of the number of steam inlet blades, but is in most cases greater and may amount to a multiple thereof. Thus, for example, in the constructional form illustrated, the number of the built in steam outlet blades is double the number of the steam inlet blades. The whole construction of the stator disc can be made especially simple, if, as shown, the cast portion of the stator device also acts as the carrier for the built in blade rim. This is not, however, imperatively necessary.

POWER FACTOR OF ALTERNATING-CURRENT SYSTEMS.

AT a recent meeting of the Institution of Electrical Engineers a paper was read by Prof. Miles Walker on "The Design of Apparatus for Improving the Power Factor of Alternating-current Systems." The paper was confined to a statement of the principles involved and a description of the phase-advancer built by the British Westinghouse Company. Prof. Walker pointed out that the main reason why the phase advancer had a fair chance of commercial success was that it was a machine of small output in comparison with the amount of change of wattless load which it was capable of effecting when used in conjunction with an induction motor of suitable size. A phase-advancer of only 30-k.v.a. capacity was capable of changing the power factor of a 1,300-k.v.a. motor from 0·88 lagging to 0·95 leading. That was to say, the motor, instead of requiring to be fed with lagging wattless current to the amount of 600 k.v.a., would relieve the generators supplying the system of a wattless load of 400 k.v.a., making a total change in the wattless power of 1,000 k.v.a. to the good. The reason was that the phase-advancer stood in the same relation to an induction motor as an exciter did to a synchronous motor. An exciter of comparatively small capacity could over-excite a synchronous motor so as to make it supply a wattless load 50 times as great, measured in k.v.a., as the rating of the exciter. Now if for some mechanical work a large induction motor must be employed, the extra cost of making that motor run at unity, or even at a leading, power factor was not very great. It was merely a question as to the cost of an advancer of which the rated output was some 3 to 6 per cent. of the rating of the motor, and the cost of a 3-phase double throw switch for putting it in and out.

The cases that would be found most suitable for the addition of a phase-advancer to induction motors were those where the motors were intended to run continuously in one direction throughout the greater part of the day. If a motor was intended to be started and stopped frequently, or reversed, then it was not suitable. Large induction motor generators, whether the continuous-current load was steady or not, might very well be fitted with phase-advancers to improve the power factor of the system to which they were connected; also large induction motors driving fans or other machinery which run continuously in one direction.

THE STRENGTH OF GEAR TEETH.*

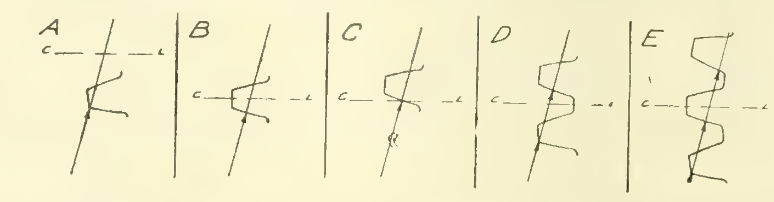
BY GUIDO H. MARX.

(*Continued from page 83.*)

THE Lewis formula is based upon the theory of flexure under the assumptions that the entire load is borne by a single tooth, the point of application of the load being the extreme end of the tooth, and the direction of the acting force being normal to the tooth profile at that point. The line of action of the force is considered carried to the centre line of the tooth (Fig. 5) with W equal to the transverse component as applied at this point. Subsequently it treats W as the load at the pitch circumference. The effects of the compressive and shear components are ignored. Fracture is assumed to take place on a plane section, the position of which is determined by inscribing a parabola of uniform strength with the vertex lying at the intersection of the centre line of the tooth and the line of action of the force. The dangerous section is the plane section containing the points of tangency of the parabola with the tooth outline. That these assumptions are too severe or unfavourable for accurately cut gears is evident from the result of these tests, as will be shown later.

TABLE III.—*Equivalent Static Breaking Loads W at Pitch Line.*—*Series* 4, *Sept.* 11-13, 1912.

10-Pitch, Cast-Iron Gear



	Position of Stressed Teeth and Equivalent Breaking Load									
	Single Tooth Loaded						2-Teeth Loaded		3-[?] Teeth Loaded	
	A		B		C		D		E	
	Test No.	W	Test No.	W	Test No.	W	Test No.	W	Test No.	W
20-T	4	1216	12	1440	1	1632	7	2112	9	1600
	5	1184	13	1476	2	1696	8	2176	10	1472
	6	1152	..	....	3	1664	..	....	11	1632
	Aver.	1184	Aver.	1458	Aver.	1664	Aver.	2144	Aver.	1568
30-T	18	1472	25	1877	14	1941	20	2603	23	1835
	19	1429	26	1707	15-16	Void	21	2176	24	1856
	..	....	27	1728	17	1899	22	2965	..	...
	Aver.	1451	Aver.	1771	Aver.	1920	Aver.	2581	Aver.	1846
40-T	31	Void	39	2416	28	2416	34	3360	36	Void
	32	1616	40	2336	29	2272	35	3360	37	2560
	33	1600	..	....	30	2208	..	....	38	2528
	Aver.	1608	Aver.	2376	Aver.	2299	Aver.	3360	Aver.	2544

To check the applicability of the Lewis formula to the form of gear tooth employed in these experiments, the teeth of the 20, 30, 40, 80, 100, and 150 tooth $14\frac{1}{2}°$ involute gears were carefully measured by gear-tooth micrometer calipers. They then, together with a theoretical rack tooth of the same system, were accurately drawn to a scale of 100 times full size. In these teeth, parabolas were inscribed by the Lewis method and the dangerous section located. The factors for strength do not seriously vary from those given by the Lewis expression for 15° involute teeth, *i.e.*, $0\cdot124-\frac{0\cdot684}{n}$. If the assumptions in the previous paragraph are correct, the Lewis formula should give the actual static breaking loads when the actual modulus of rupture is inserted for s. To test this, consider first the case of a 20-tooth 10-pitch $1\frac{1}{16}$in. face, cast-iron pinion, the material having a modulus of rupture of 39,000. Substitution in the Lewis formula

$$W=spf\left(0\cdot124-\frac{0\cdot684}{n}\right)$$

gives

$$W=38{,}000\times0\cdot31416\times1\cdot0625\left(0\cdot124-\frac{0\cdot684}{20}\right)$$

therefore $W=1{,}170$lbs.

But from curve A, Fig. 3, it is seen that the static strength (*i.e.*, equivalent breaking load at zero pitch velocity) is approximately 1,650lbs. for a 20-tooth pinion in mesh with a 30-tooth gear. The value computed by the Lewis formula, when using the real modulus of rupture, is only two-thirds of the actual value shown by the tests. Similarly, the Lewis formula gives a value of 1,317lbs. for the static breaking strength of the 30-tooth gear, while Fig. 4 shows this to be, for a 30-tooth meshing with a 40-tooth, 2,260lbs. Again the Lewis value is much too low, being but 60 per cent. of the actual test result.

These discrepancies demonstrate that the assumptions upon which the Lewis formula are based are too severe, and they indicate the necessity of taking into consideration the length of the arc of action; for if the length of the arc of action exceeds the pitch arc, it is evident that the previously engaging teeth will not have gone out of action at the time when the load first comes on the newly engaging teeth, and it is only at the instant of engagement or disengagement that the load can be applied at the end of a tooth. This is not only theoretically so, but it can be counted on with reasonable certainty for modern, accurately cut gears. It must be borne in mind that this is the least stiff position of the tooth, and that it would therefore tend to yield slightly under the load, thus allowing another pair of teeth to come into engagement or remain in engagement. This elastic yielding would be apt to make up for the slight errors in tooth spacing.

In order to test the actual static strength of the teeth in various positions, and with one, two, or, if possible, three pairs engaging simultaneously, experiments were carried out with results as shown in Table III. The loads were applied in each case by a steel 30-tooth pinion with all teeth save three single ones, two pairs of two, and one set of three having been milled off in such a way as to leave gaps between the remaining teeth. Because of this there could be positive assurance that only as many pairs of teeth engaged in any test as was intended. The gears were set up with the teeth engaging in the position desired, the cast-iron gear to be tested being the one on the brake shaft and a surface gauge being used to test the accuracy of conditions. All play was taken up and the brake was tightened down with emery cloth between it and the wheel, so as to prevent all slip. The breaking power was supplied by means of a special hand-operated lever instead of by motor. Position A corresponds to the loading assumptions of the Lewis formula, and it is interesting to compare these results with those obtained by using the Lewis formula with a modulus of rupture of 39,000lbs. Table IV. presents this comparison in concise form.

TABLE IV.—*Equivalent Breaking Loads.*

Size of gear	20 T	30 T	40 T
W by test, position A	1184	1451	1608
W computed by Lewis formula	1170	1317	1392

The test values of W, as given in Table IV., correspond to a formula for this position of engagement and static conditions:

$$W=spf\left(0\cdot154-\frac{1\cdot26}{n}\right)$$

This equation would make the static strength of single teeth vary from that of a theoretically correct rack tooth down to a 20-tooth pinion in the ratio of 0·154 to 0·091; in other words, the rack tooth would have 1·69 times the strength of the 20-tooth pinion. The Lewis formula would give a ratio of 0·124 to 0·090 for the same gears. The discrepancy can be explained by the fact that the theory of flexure is recognised as only approximately correct, particularly for oblique forces, material which has not the same strength in tension as in compression, and for stresses beyond the elastic limit. Furthermore, the Lewis factors neglect entirely the effect of the angularity of the force in producing a compressive stress. In the case of the 20-tooth gear this angularity is such as to make the compressive component of the acting force more than 50 per cent. of the transverse component. The theory of flexure upon which the Lewis formula is based would have the fracture occur on a plane section (as shown in Fig. 5) and would have the breaking loads vary, approximately as the square of the thickness of the tooth at this section. As a

*Abstract of paper read before the American Society of Mechanical Engineers.

matter of fact the fracture of the teeth in every case took place lower down on the root than at the points of tangency of parabolas inscribed on the Lewis assumption. The fractures took place rather at the points of tangency of parabolas constructed for loads applied at the pitch points, as shown in Fig. 6, and the breaking loads varied more nearly in proportion to the squares of the thickness at this section. The surface of the break invariably was in the form of a curve running down into the root as shown and in no case did a tooth break square across.

Mention is made above of the necessity of taking the arc of action into consideration in dealing with the load-carrying strength of gear teeth. It would seem that the breaking load of a gear would depend not solely upon itself, but also upon the gear with which it meshed. The larger the meshing gear, the greater the arc of action; and the greater the arc of action, the more likely the load is to be borne on two or more pairs of teeth simultaneously, and the less likely that the entire load will fall on a single tooth in its position of least strength. It is desirable to see, then, what effect, if any, the length of arc of action has on the breaking load. To see what the effect was under static (zero pitch velocity) conditions a series of tests (Series 5) was conducted. Tests were made of 30-tooth gears in mesh with 30, 40, 60, and 80-tooth gears. It was found in making these tests that the position of the teeth in engagement made a vast difference in results. It was therefore necessary to find by trial the position of engagement corresponding to the least carrying power of the tooth. The results are given in Table V. There is nothing to account for the foregoing variation in strength except the differences in arc of action. It was the intention to carry similar tests out on 30-tooth meshing with 80-tooth and 100-tooth, but it was found in trying the 30 and 80 pair, that the rim of the 80-tooth broke, cracking the arms and hub, before a breaking load of the teeth could be reached. Fig. 7, curve *A*, shows the results of these tests, the ordinates being equivalent breaking loads at pitch point, and the abscissæ being arcs of contact. There being no unbroken 20-tooth gears to use in series 5, the value for static strength of 30-tooth meshing with 20-teeth (arc of action, 0·53938in.) is taken from Fig. 3, curve *A*.

TABLE V.—*Static Strength. Series 5, September 26-27, 1912.*

Breaking Loads *W* of 30T in mesh with

30T			40T			60T		
Series	Test	*W*	Series	Test	*W*	Series	Test	*W*
4	23	1835	5	1	2480	5	14	2453
4	24	1856	5	6	2368	5	15	2453
5	17	2475	5	7	2080			
5	18	2304	5	8	2112			
Average 2118			Average 2260			Average 2453		
Arc of action 0·61158in.			Arc of action 0·62814in.			Arc of action 0·64919in.		

From Table IV. it is seen that the static strength of a single tooth of a 30-tooth gear in its weakest position = 1,451lbs. This would measure the strength of teeth with an arc of action

of 0·314in. or less, *i.e.* when the $\frac{\text{arc of action}}{\text{pitch arc}} \overset{+}{>} 1$,

From Fig. 7, curve *A*, for a 30-tooth meshing with a 20-tooth the arc of action equals 0·53938in. and the corresponding $W = 1{,}660$lbs. From these facts and Table V. it is possible to construct Table VI. to show the relationship, under static conditions, existing between length of arc of action and equivalent breaking load. The range in breaking strength

TABLE VI.—*Relation between Arc of Action and Equivalent Static Load.*

Ratio $\frac{\text{Arc of Action}}{\text{Pitch Arc}}$	$\frac{0{\cdot}31416}{0{\cdot}31416} = 1$	$\frac{0{\cdot}53938}{0{\cdot}31416}$ 1·72	$\frac{0{\cdot}61158}{0{\cdot}31416} = 1{\cdot}95$	$\frac{0{\cdot}68214}{0{\cdot}31416} = 2$	$\frac{0{\cdot}64919}{0{\cdot}31416} = 2{\cdot}07$
Breaking Load	1451	1660	2118	2260	2453
Ratio $\frac{\text{Breaking Load}}{1451}$	1	1 14	1 46	1·56	1·69

due to varying arcs of action, from 1 to 1·69 shown by this table, is as great as that due to form between 20 teeth and 150 teeth; and it is greater than that due to variations in velocity from zero pitch speed to over 500ft. per minute. If form of tooth and velocity are of sufficient importance to be taken into account in a formula for gear tooth strength it is demonstrated that there should also be introduced a factor for arc of action.

Further light is thrown upon the extent of the influence of the length of arc of action, if from series 1 and 2 the tests involving 30-tooth gears made at nearly a uniform pitch velocity are selected. The results of such tests made at about 290ft. pitch velocity are shown graphically in Fig. 7, curve *B*. There are no running experiments involving an arc of action

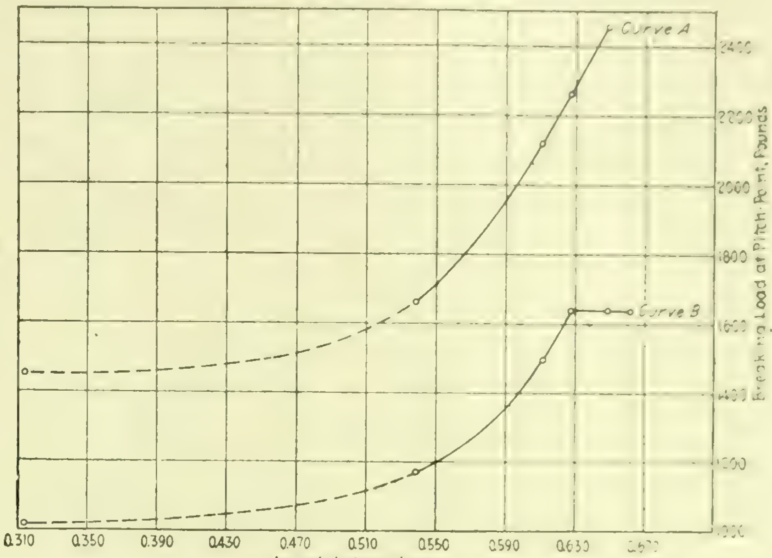


FIG. 7.—RELATION BETWEEN EQUIVALENT BREAKING LOAD AND ARC OF CONTACT.

of 0·31416. But from Figs. 3 and 4 it is clear that the breaking strength at 300ft. per minute is about 70 per cent. of the static strength. It is therefore not improper to assume that the breaking strength for an arc of contact of 0·31416 at a pitch velocity of 300ft. per minute would be 70 per cent. of 1,451lbs., or 1,016lbs. On this assumption and the data of Table VI., Table VII. has been computed. It is interesting to note how closely this agrees with Table IV.

TABLE VII.—*Relation between Arc of Action and Breaking Load under Running Conditions.*

Ratio: Arc of Action / Pitch Arc	$\frac{0{\cdot}31416}{0{\cdot}31416} = 1$	$\frac{0{\cdot}53935}{0{\cdot}31416}$ 1·72	$\frac{0{\cdot}61158}{0{\cdot}31416} - 1{\cdot}95$	$\frac{0{\cdot}62814}{0{\cdot}31416}$ 2	$\frac{0{\cdot}64919}{0{\cdot}31416}$ 2·07	$\frac{[illegible]}{0{\cdot}31416} = 2{\cdot}11$
Breaking Load	1016	1169	1493	1637	1636	[illegible]
Ratio: $\frac{\text{Breaking Load}}{1016}$	1	1·15	1·47	1·61	1·61	[illegible]

TABLE VIII.—*Coefficients Based on Arc of Action.*

Ratio: $\frac{\text{Arc of Action}}{\text{Pitch Arc}}$	1	1·4	1·6	1·7	1·8	1·9	[illegible]	[illegible]
Corresponding *a*	1	1·05	1·1	1·15	1·24	1·38	1·47	[illegible]

The results in Tables VI. and VII. may now be combined and a table of coefficients *a* constructed by which the effect of the arc of action may be introduced into the formula for the strength. The entire formula as derived from these experiments for the safe equivalent load at pitch line may now be written

$$W = \frac{spf}{k}\left(0{\cdot}154 - \frac{1{\cdot}26}{n}\right) va$$

in which

W = safe working load at pitch line in pounds.
s = modulus of rupture = 39,000 in these tests but ordinarily to be taken = 36,000.
p = circular pitch in inches.
f = width of face in inches.
k = factor of safety.
n = number of teeth in gear.
v = velocity coefficient from Table II.
a = arc of action coefficient from Table VIII.

The general effect of arcs of action and of pitch speed on the breaking strength of gear teeth as found in these experiments can best be seen by combining Fig. 3, curve *A*, Fig. 4 and Fig. 7, curves *A* and *B*, into a single isometric chart. This is done in Fig. 8. The ordinates, as heretofore, represent equivalent breaking loads at pitch point in pounds. One set of abscissæ represents pitch speeds in feet per minute; the other set represents lengths of arc of action in inches.

To complete the record of this experimentation mention should be made of the tests which were designated as series 3. In planning these it was thought that the remaining unbroken gears could have their width of face turned down to one-half its previous value, and then, the teeth being theoretically just half as strong as those of the full-width gears, tests might be conducted at higher pitch speeds and the gears ruptured within the capacity of the motor. The observed breaking load could then be doubled, and the breaking load of the full-

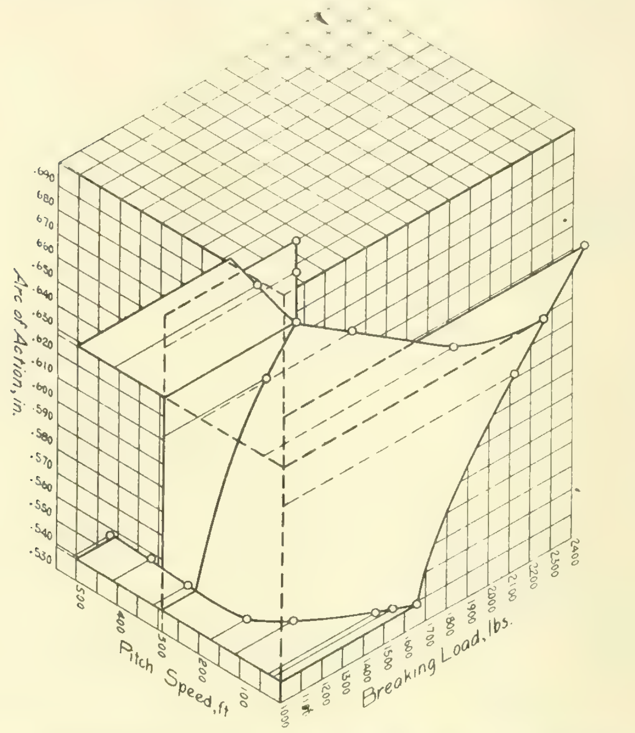


FIG. 8.—RELATIONS BETWEEN ARC OF ACTION, PITCH SPEED, AND BREAKING LOAD, SHOWN ISOMETRICALLY.

width gears and points so obtained be used to extend the curve of direct observations. The results of a very few tests proved that this could not be done. The data and results are briefly tabulated in Table IX. It is evident from tests 48-49 and 50-51

TABLE IX.—*Series* 3, *July* 1st, 1912.

Test No.	Width of Face.	Change Gears. Sprocket.	Change Gears. Intermediate	Test Gears. Intermediate	Test Gears. Brake.	Motor R.P.M.	Net Brake Load, Lb.	Pitch Speed Brake Gear. Ft. per Min.	Equivalent Load at Teeth. Lb.
48	17/32	70	40	30	30	720	28	508·18	597
49	1 1/16	70	40	30	30	720	66	508·18	1408
50	17/32	40	20	30	30	720	28	580·77	597
51	1 1/16	40	20	30	30	720	62	580·77	Could not break. Circuit Breaker out.
52	1 1/16	70	40	30	30	720	66	508·18	1408 Same Gears as Test 51.

that the half-width teeth have not one-half the strength of the full-width teeth. Only speculations can be offered as to this apparent discrepancy. It may be that the wider teeth forced better alignment conditions without unduly stressing the teeth. Or it may be that the additional mass plays some part in shock absorption. But, since observations could not be used to supplement those on full-width gears, no further runs were made.

It would appear that the factors of safety in common use, in so far as breaking strength of the teeth is concerned, while they might properly serve for rough cast gears, are much too large for modern, accurately cut gears; and that Mr. Lewis and Mr. Christie were quite right in assuming that the factor of safety at any speed need not be more than double that which will suffice for the slowest speed.

A few words may be added about the general design of the gears. The almost invariable breaking of the 20-tooth gears, $1\frac{1}{16}$in. bore, $\frac{1}{4}$in. keyway, tends to indicate that this is just about the maximum limit of bore which can be used with these gears while getting the maximum out of the tooth strength. Any larger bore, it seems, would simply allow these gears to split at the keyway without stripping any teeth. Of the 30 and 40-tooth gears, and of the proportions of the 60-tooth there can be no criticism. In all cases the failure came at the teeth, although it is indicated that the 60-tooth gears could have borne heavier loads if they had been solid. As a whole the tests involving gears with more than 60 teeth were indecisive so far as throwing any light on the strength of the teeth was concerned. These gears were not solid nor webbed but had arms, and their less rigid design allowed them to yield and fracture at rim, arms, and hub before the breaking strength of the teeth could be reached. To bring the rest of the gear up to the strength of the teeth would seem to require a larger diameter of hub, thicker rims, and heavier arms. In loading the gears up to the breaking strength of the teeth considerable difficulty was encountered with shearing and battering of keys. This was practically overcome by the use of hardened tool-steel keys.

OIL FUEL FOR POWER PURPOSES.

IN the course of a paper recently read before the Liverpool section of the Society of Chemical Industry, Mr. W. Hamilton Patterson pointed out the ambiguity existing in the nomenclature of various liquid fuel products, *e.g.*, the terms paraffin, benzine, solar oil, naphtha, &c., and proposed the use of the term "oil fuel" for products used for internal combustion, and "fuel oil" for those used for external combustion, *e.g.*, burning under a boiler for steam raising. There was a difference in the requirements in the two cases. In oil fuels, volatility was of greater importance, and it was necessary to obtain oils which would neither corrode nor give trouble in the cylinders on explosion or burning. In fuel oils, on the other hand, the more vital factors were cheapness, a fairly high flash point, and high calorific value. When liquid fuels had to compete with coal, only crude products, by-products, or residues could be considered. The available sources might be divided as follows: (1) Crude petroleum or its residues and products; (2) tar oils from coal distillation, coking, or producer plants, especially bituminous coal producers; (3) liquids or oils from vegetable or animal sources, *e.g.*, alcohol (at present of little importance); and (4) oils from lignite, peat, wood, or shale. A gas oil which gave trouble in Diesel engines was found to have a net calorific value of 16,153 B.Th.U., with 5·98 per cent. of hydrogen and 0·67 per cent. of sulphur, whereas the net calorific value of a petroleum oil that worked well in those engines was 18,344 B.Th.U., and the percentages of hydrogen and sulphur respectively 12·92 and 0·17. Figures were put forward illustrating sudden changes at a certain temperature for each oil, and it was pointed out that irregularities might arise if an engine was taking its feed at that particular temperature.

Wireless Telegraphy: Committee of Enquiry Appointed.—In accordance with the recommendation of the Select Committee of the House of Commons on the Marconi Contract, the Postmaster-General has appointed a Committee to report on the merits of the existing systems of long distance wireless telegraphy, and in particular as to their capacity for continuous communication over the distances required by the Imperial chain. The Committee will consist of Mr. Justice Parker (chairman); Mr. W. Duddell, F.R.S., President of the Institute of Electrical Engineers; Mr. R. T. Glazebrook, C.B., director of the National Laboratory, Past-President of the Institute of Electrical Engineers; Sir Alexander Kennedy, F.R.S., Past-President of the Institute of Mechanical and Civil Engineers; Mr. James Swinburne, F.R.S., Past-President of the Institute of Electrical Engineers. They have been requested, as desired by the Select Committee, in view of the urgency of the question, to report as soon as possible, and in any case within three months from the present date.

INDICATORS.*

BY JAMES G. STEWART.

(*Continued from page 92.*)

Discussion of Results of the Experiments on the Pressure-indicating Mechanism of Indicators.†—The Crosby indicator, despite the accuracy of its workmanship, is very sensitive to small defects; that is, small inaccuracies in workmanship of certain parts lead to large errors in indicating. The piston is secured to the ball on the indicator spring; any inaccuracy in manufacture which results in deflecting that ball from its true position in the axis of the indicator cylinder will, when the piston and spring are put in place, result in a side pressure of the piston on the cylinder wall. Thus friction is introduced. If the inaccuracy be in the indicator cylinder or cover the amount of side pressure will be greater for stiffer springs, and so the friction will be proportional to the stiffness of the spring. This effect is seen in Fig. 7. If there is any inaccuracy in placing the ball of the spring exactly in the axis of the spring this will introduce a side thrust and a consequent error; such an error does exist, as is shown by Fig. 9.

As it happens, all errors are much greater in the No. 2 Crosby than in the No. 1. The most readily comparable point is that at atmospheric pressure using 400 springs.

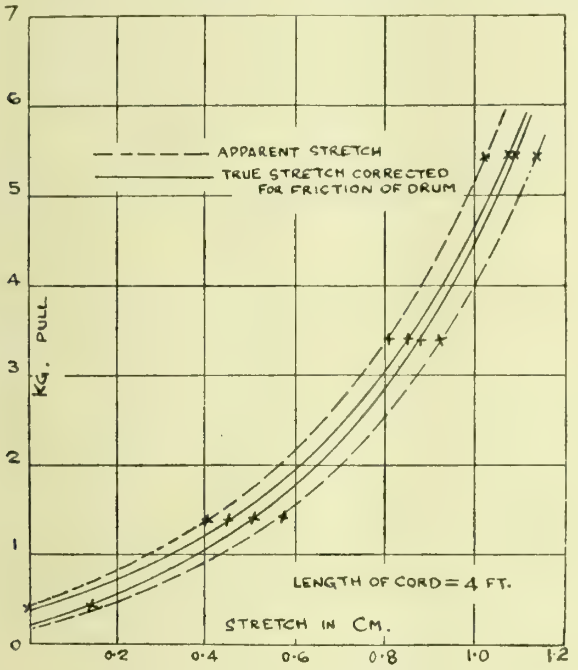


FIG. 14.—STRETCH OF INDICATOR CORD.

From the No. 2 Crosby we would expect $3\frac{1}{2}$lbs. per inch² friction (Fig. 7, $\frac{3}{8}$-turn pencil pressure), whereas the No. 1 Crosby only showed a friction of 1lb. per inch² under the same conditions. There can thus be great differences between two indicators, and it becomes important to be able to select good ones. A fair clue to the quality of an indicator can be obtained by testing it for friction by Reynolds's static method, using not only the weak spring but springs of all stiffnesses. With stiff springs the error should be so small that it cannot be measured. Doing this on the No. 2 indicator, the author found errors of the same order of largeness as those found kinetically; but by the nature of the case the measurement is inaccurate. On the other hand, the friction measured statically on the No. 1 indicator was small with weak springs and unmeasurable with stiff springs. In making such a measurement as this it is essential that there should be no play in the joints of the pencil gear, or else that its amount should be separately determined and a correction made.

The irregularity in the behaviour of indicators is very unsatisfactory; it means that in any accurate work indicator diagrams cannot be accepted unless accompanied by a statement of the peculiar behaviour of the indicator used in taking them. With regard to past work, it would be necessary, if its results are to be accepted, that the experimenter should get back to his original indicator and supplement his work by a statement of its errors. That error which varies with the pressure and which is due to restraining couples is the most troublesome; its presence can only be detected by some such method as that used in these experiments. The difficulty of detecting even its presence is no reason for believing it to be small. It is probably not too much to say that the indicated horse-power is frequently 10 per cent. or more greater than the true value. The author's friend, Dr. W. E. Fisher, has drawn his attention to an engine test which shows the presence of errors of this magnitude. With diagrams of the ordinary form the effect of friction is to increase the diagram, and when this friction increases with the pressure, the increase in the size of the diagram will be greater for higher initial and back pressures in the cylinder. This effect Dr. Fisher obtained by working a Willans engine —(1) condensing, (2) non-condensing; maintaining throughout the same brake horse-power. He used selected indicators. He found an increase of indicated horse-power between the two cases of 3 per cent. using Crosby indicators, and an increase of 4·6 per cent. using McInnes Dobbie indicators. The McInnes Dobbie indicators throughout gave much larger indicated horse-powers than the Crosby indicators; between the indicated horse-power (condensing) as obtained by the Crosby indicators and the indicated horse-power (non-condensing) as obtained by the McInnes Dobbie indicator there is as great a difference as 10 per cent. If to this be added the percentage error in the Crosby, we obtain the result that the indicated horse-power as obtained by the McInnes Dobbie indicator is greater than the true horse-power by more than 10 per cent. In this experiment the assumption is made that the mechanical efficiency of the engine is constant when the brake horse-power is maintained constant—an assumption which there is much reason to believe is true, or very nearly so.

It has been assumed that the friction, as measured from the oscillation diagrams, is the same as that in the indicator when the motion is that of the ordinary indicator diagram. This requires justification. It has already been pointed out in the analysis of the oscillation diagram that the friction is practically independent of the velocity; consequently its magnitude is equally great even when drawing a constant pressure line. It is generally believed that the vibration of an engine is sufficient to relieve the indicator of all solid friction. To determine whether this was true, an indicator was fitted to a Belliss high-speed engine and a weak spring was put in the indicator. The drum was rotated by the indicator gear. The indicator cock was open to atmosphere throughout. The indicator pencil was deflected first above and then below the atmospheric line, as in the Reynolds static friction test. On releasing it gently, it took a final position which even after many revolutions was almost as far distant from the atmospheric line as it would have been if it had not been subject to any vibration. With heavier springs the possibility of relieving friction by vibration is still less. The motion of the piston and pencil gear may cause additional vibration. But such was present in the oscillation experiments, and its effect is therefore included in the friction as obtained from them. The same result was obtained on the Premier gas engine. The particular Hopkinson indicator which was tested showed errors much greater than the Crosby. It is probable that its errors may be considerably lessened by change in the nature of the rubbing surfaces of the supports and spring, but it is not likely to be altogether eliminated. A peculiarity of this method of support is that there is a range corresponding to points within the loop, Fig. 13, throughout which there is no slipping of the beam in its supports. Its stiffness as a spring is, under these conditions, greater, and consequently its periodic time is much less than that corresponding to slipping in the supports. Probably this rapid oscillation is the secondary oscillation seen superimposed on the main oscillation of Fig. 12. That friction was negligibly small for conditions corresponding to points within the loop was

* Paper read before the Institution of Mechanical Engineers, January 17th, 1913.

† In this discussion reference will be made to only the Crosby and the Hopkinson indicators. This does not mean that other indicators are free from the faults of these; in fact, it is the author's opinion that there is not a mechanical type indicator superior to the Crosby nor an optical one which, within his knowledge, is superior to the Hopkinson.

evident, small oscillations set up within this range being very slowly damped.

Experiments to Determine the Periodic Times of Oscillating of the Pencil. — For these experiments the drum of the indicator was insulated and a spark made to pass at timed intervals from the pencil point through the paper to the drum, piercing in its passage a hole in the paper. The pencil was set in oscillation and the drum rotated as in the friction experiments. The result was a diagram the same as previously obtained, with the addition of the small pierced holes caused by the spark. To obtain the timed spark, a commutator driven by a small motor was put into the low-tension circuit of an induction coil and the trembler of the coil was put out of action. The small motor was a 3-phase induction one;

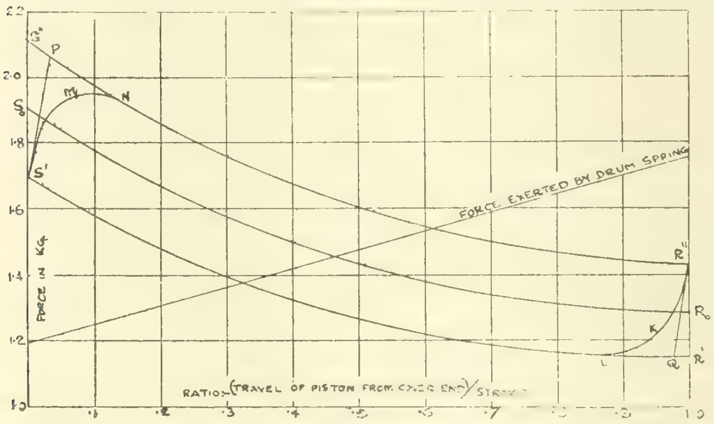


FIG. 15.—DIAGRAM OF FORCES ON DRUM CORD.

in these experiments its slip has been neglected. The frequency of the supply was known accurately. The estimation of the time interval between sparks was thus fairly accurate. Much greater errors were involved in the variable resistance offered by the paper to the passage of the spark. To obtain pierced holes in the paper it was found necessary to dry it carefully. It was found that, due to inequalities in the paper, the spark did not always take the shortest path between the pencil point and the drum, the spark hole being in some cases almost $\frac{1}{32}$ in. from the pencil line. To eliminate this error as far as possible a judicious choice of diagrams was made and an average taken. In choosing diagrams, those were selected which showed that the sparks had passed at times when the pencil was moving with its maximum velocity; this minimised the effect of the error. The number of oscillations or fractions of oscillations occurring between two or three spark intervals could easily be measured from the diagrams; a simple calculation then gave the time of one oscillation.

TABLE I.—*Periodic Times of Oscillations (Crosby Indicator).*

Scale of Spring.	Equivalent Mass at Piston	Rate of Spring. (Dyns. per cm.)	Periodic Times. Calculated.	Periodic Times. Observed.	Percentage Excess of Observed over Calculated.
	Grammes.		Second.	Second	Per cent.
20	58·0	$5{\cdot}27 \times 10^6$	0·021	0·0199	$-5\frac{1}{2}$
80	58·7	$21{\cdot}08 \times 10^6$	0·0105	0·0103	-2
160	60·3	$42{\cdot}16 \times 10^6$	0·00752	0·00747	$-\frac{1}{2}$
240	61·0	$63{\cdot}24 \times 10^6$	0·00618	0·0066	$+6{\cdot}4$

The results which were obtained are given in Table I., which also gives the calculated values of the equivalent mass M and the corresponding calculated periodic times of oscillations with different springs. (See Appendix II.). The last column gives the percentage divergence of the experimental result from the calculated. The agreement generally is very close considering the difficulties of measuring so very small periods of time and the errors involved in the assumptions made in obtaining the calculated values. There is, however, a noticeable progressive lengthening of the period from experiment compared with that from calculation, in advancing from lighter to heavier springs. This is not satisfactorily explained by any of the causes of error mentioned above. Despite these variations, the calculated values are so near the experimental that for most practical cases it will be sufficient to take them as accurate.

Other Sources of Error in Pressure Indication.—Mention should, perhaps, be made of some of these. They are, however, better known than errors due to friction and are consequently guarded against by all careful experimenters:—

(1) Errors due to water in the indicator or in its connection with the cylinder. The effect of a mass of water on the indicator cannot be predicted; not only does it alter the shape of the diagram, but it may introduce a large error in the measurement of mean pressure, particularly in high-speed engines.

(2) The connection between the indicator and the cylinder may be of too small a bore. This will not generally introduce any great error except in cases in which water may possibly get into it. In particular cases oscillations of the steam or gas may be set up in this connecting pipe. This is more common in gas-engine work where a long pipe cannot always be avoided, and where the necessity for a large bore is not so evident as in steam-engine work.

(3) The scale of the spring may not be known with accuracy. Springs can be calibrated accurately at room temperatures or at 212° Fah. Between these two temperatures there is a difference in the rate of 2 to 3 per cent. In steam-engine work no appreciable error is involved in assuming that in working conditions the temperature of the springs, if internal springs, is 212° Fah. In gas-engine work no such assumption can be accepted as accurate; all that can be done is to form a rough estimate of the probable working temperature of the spring when used in the particular way adopted.

(4) Slackness in any of the joints of the pencil gear or in the screw of the piston rod is a more serious trouble and one which it is extremely difficult to avoid; in fact, the best of indicators of the mechanical type readily develop looseness of the joints when used. For accurate work this slackness must be taken up or the indicator rejected.

(5) Sampling of diagrams has scarcely received sufficient attention. Without proper care large errors in the indicated power may be introduced. The difficulty is greatest where the area of the diagrams is subject to large variation. In a steam engine with a good governor sampling is comparatively easy, but in a gas engine the variation in diagrams is often large, particularly if it is working on power gas. In a gas-engine test in which cars, each of three working cycles, were taken every five minutes throughout an hour (that is, 36 diagrams in all), a difference of 1·7 per cent. was found between the average of all the diagrams and the average of the first 30. The effect of large or small diagrams in causing such a divergence becomes less as the total number of diagrams increases. In the particular test instanced, in which the load was artificial and of constant amount, the maximum variation of one of the sets of three diagrams from the mean was about $8\frac{1}{2}$ per cent. In one instance two successive sets each gave $8\frac{1}{2}$ per cent. above

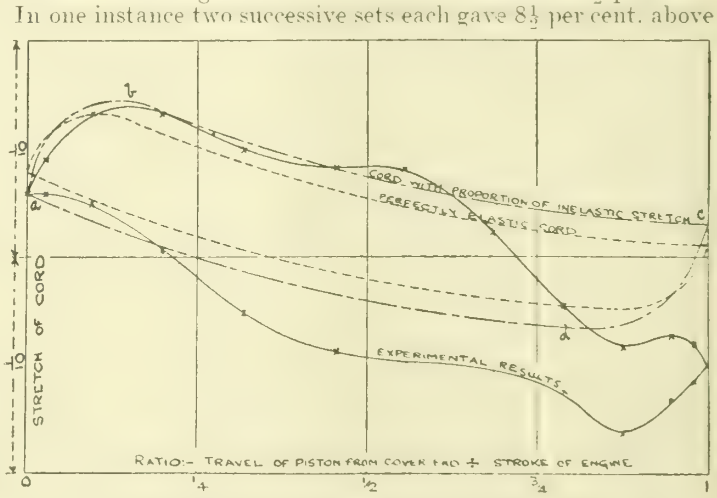


FIG. 16.—DRUM ERRORS CAUSED BY YIELDING OF THE INDICATOR CORD. COMPARISON BETWEEN THEORY AND EXPERIMENT.

the mean. Roughly, these occurring together represent an excess of 17 per cent. above the mean. In order that two such diagrams occurring at the end of a test should not affect the final result by more than $\frac{1}{2}$ per cent. it would be necessary to take 34 sets of diagrams, that is, almost three times the number actually taken. Mond gas was used in the test and the mixture was weak; with richer mixtures the variations are not so large. In a test giving a mean pressure of 92lbs. per inch^2 the greatest variation from the mean of any one set of diagrams was 5 per cent. In order that two such sets

occurring at the end of a test should not affect the results by more than ½ per cent., 20 sets of diagrams would require to be taken.

(6) In measuring the area of the diagrams inaccuracies may be introduced. The usual method of planimetering each diagram and averaging is probably most accurate, as chance errors will average out. This can only be done when the pressure scale of the diagram is uniform, a condition which is found in the Crosby but not in the Hopkinson indicator.

Mechanism for Recording Position of Engine Piston.—In the mechanical type indicator the drum with its associated parts records the position of the piston. In the optical indicator this is done by that part of the mechanism which causes the crossways motion of the spot of light. The motion will be true if the indicator paper or the spot of light moves in exact accordance with the motion of the piston. Errors are introduced into the motion if the mechanism is subjected to variable forces and if it yields under these forces. The forces to which it is subjected in the case of the drum are: (1) that of the drum spring; (2) that due to inertia of the moving parts; (3) that of frictional resistance. In the case of the optical indicator there are similar forces, but both they and the yielding of the mechanism can in general be reduced until their effect is negligible. A drum must have a cord or flexible wire, yielding of which cannot be avoided.

Errors are often introduced by faulty design of the indicator driving mechanism. These are external to the indicator and, as they are well understood, they will not be discussed here. Geometrical errors are always present in the optical indicator when a flat screen is used, but by careful design they may be made negligibly small.

The Inertia of the Moving Parts.—The moment of inertia about its axis of rotation of the Crosby drum with its paper and with part of the drum spring and cord is roughly 415 g.-cm^2. This was obtained partly by an oscillation experiment on the drum and partly by calculation. For convenience in calculation a mass of 110 grammes situated on the surface of the paper may be taken as giving the same moment of inertia about the axis as the drum and its associated parts. This may be called the equivalent mass of the drum.

Stretching of the Cord or Wire.—Any cord shows considerable variation of length under varying load, even when precautions have been taken to initially stretch the cord. Fig. 14 shows the result of a test on a 4ft. length of Crosby cord, which had previously been stretched by hanging a weight of 8½lbs. to it for 24 hours. In use the pull on the cord does not exceed half this amount and is usually much less. To measure the stretch the indicator was put in place on the engine (this was done for convenience, but the engine was at rest throughout). The drum axis in this position was horizontal; the cord was attached to the drum in the usual way and its lower end was fastened to the lever of the indicator gear, which was vertically under the indicator and was rigid. Another cord was attached to the drum and hung over its other side. To the end of this other cord weights were hung. As the drum spring had previously been removed, these weights gave a measure of the pull on the string, corrections being made for the friction of the drum. As such cord is not perfectly elastic, the test was performed with increasing and diminishing loads. To obtain the correction for friction both cords were allowed to hang free and equal weights were hung to each. Additional weights were hung to one cord until the friction was just overcome. This gave a measure of the force required to overcome friction for a load on the drum corresponding to the weights on the cords. If the indicator had not been perfectly rigid under the forces applied to it in measuring the stretch of the cord a correction would have to be applied to the above results. No appreciable want of rigidity was present, for no effect was apparent on hanging a heavy weight to the end of the drum spindle or by taking it off.

The Frictional Resistance to Motion of the Drum and the Rate of the Drum Spring.—These were measured statically by securing the indicator in a support with the axis of its drum horizontal, hanging weights to the cord and marking the positions of the drum for each weight for increasing and diminishing loads. The spring was found to have a rate of 0·14 kg. per cm. movement of the diagram, and the friction of the drum was found on an average equal to 0·17 kg. The friction increased with the load, but the variation was not very great. 0·17 kg. corresponds to a pull on the cord of about 1½ kg., which may be taken as the pull under working conditions.

Theory of Drum Motion. In this theory it will be assumed, as a first approximation, that the motion of the drum is true, in order to be able to calculate the variation of pull on the cord due to acceleration of the moving parts; also, in the first instance, the cord will be assumed to be perfectly elastic, its rate of stretch being 0·357 cm. per kilogramme, which is the rate corresponding to the average pull.

The case corresponding to the experiments, which are given later, is taken. The forces which exert a pull on the cord are: (1) that of the drum spring; (2) that due to the acceleration of the moving parts; (3) the friction of the drum. The mean pull on the drum spring was 1·47 kg. and its rate 0·14 kg. per cm. Friction of the drum = 0·17 kg. The forces due to acceleration are obtained by calculation from the following data: revolutions per minute of engine 540; length of diagram = 3·92 cm. (1·54in.); equivalent mass of drum, &c., at surface of paper = 110 g.; ratio of crank to connecting rod one-fifth; the speed of rotation of the crank is assumed to be uniform. As the calculation is similar to that of the inertia forces of the piston and piston rod in the determination of the turning moment exerted at the crank, it will not be given here. These forces are shown graphically in the diagram, Fig. 15. R_0S^0 is the resultant of the inertia forces and the force exerted by the drum spring for the inward motion of the drum. The effect of friction is to reduce the

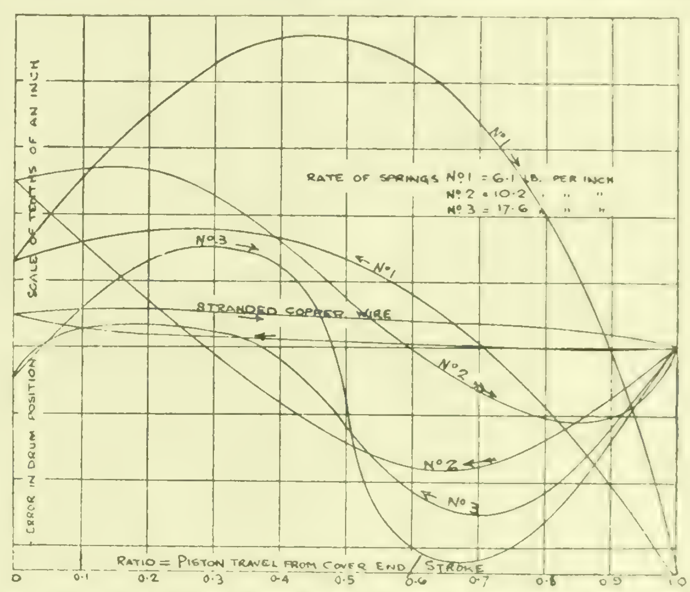


FIG. 17. ERRORS IN DRUM MOTION WHEN SPRINGS ARE INTRODUCED INTO DRIVE

pull on the cord by an amount equal to the friction; the resultant pull on the cord for inward motion of the drum is therefore R′S′. For outward motion the pull of the cord must overcome the friction as well as give the drum its proper motion, and consequently the resultant pull on it, represented in figure by S″R″, is greater by the force required to overcome friction than the pull for a frictionless drum. The forces therefore required to give the drum its true motion are represented by R′S′S″R″. Under these forces, however, the string stretches, introducing an error into the motion, and so to some extent modifying the resultant pull on the cord. This is particularly so at the ends of the diagram. There can be no sudden transition from the conditions of S′ to those of S″, or from those of R″ to those of R′; instead, some such gradual changes as are shown by S′MN and R″KL would take place. If it were possible for the drum to actually pause until the tension in the cord rose or fell to that theoretically required to make the remainder of the motion true, the changes in pull would be represented by S′PN and R″QL; but the conditions required for an actual pause cannot be attained, since the pull exerted by the string is, except in exceptional cases, in excess of the friction of the drum. The error due to stretch of the cord for the cycle of forces R″KLS′MNR″ has been calculated, and is plotted in Fig. 16. Throughout the cord has been assumed perfectly elastic. Actually it has an inelastic stretch of roughly 0·1 cm. (see Fig. 14). This will cause an additional lag of 0·2 cm. for both outward and inward motion. The

diagram of errors therefore becomes *abcda*, obtained theoretically.

Experimental Determination of Drum Motion Errors.—As the theoretical estimation of the error can be made without much trouble, it becomes of value to know whether it is verified quantitatively by experiment. To this end experiments were made on a Belliss and Morcom high-speed engine at 540 revs. per minute. The method of passing sparks from the pencil through the paper to the drum at definite positions of the piston was used. This method had been used by Dr. Brightmore in his experiments. In the author's experiments for convenience a circular commutator was used, which was bolted to the end of the shaft. A brush consisting of a single strip of copper pressed against the commutator. The commutator had three brass segments on its circumference and thus three breaks occurred in each revolution. This commutator served to make and break the current of an induction coil, thus taking the place of the trembler, which was put out of action. Sparks only passed at the break of the current in the primary, under which condition the lag between the time of break and the passage of the spark is so very small that it may generally be neglected. The brush could be adjusted in position relative to a stationary graduated disc. By this adjustment a spark could be timed to pass and so pierce the indicator paper at any chosen position of the crank.

In these experiments the brush was given eight different positions. For each position of the brush there were three sparks. In all 24 points were investigated, corresponding to each 15° of crank motion. To find the true positions which the drum ought to have occupied at the passage of the sparks a static experiment was made; this was necessary, as the indicator gear did not give a motion sufficiently correct to enable one to calculate the true positions. In the static experiment the engine was successively set to each position at which sparks passed in the kinetic experiments. A mark for each position was made on the indicator diagram by moving the pencil by hand. Each position was approached in both directions and a mean taken. To eliminate errors due to stretch of the cord the cord was replaced by a stranded copper wire. The difference between the kinetic and static positions of the drum for any one crank position gives the error in the drum position. In Fig. 16 these errors have been plotted on a base which represents proportion of stroke. As the ordinates are the same as those for the curve of errors which has already been plotted on Fig. 16, the two results can readily be compared.

From a consideration of these it appears that the error found experimentally is slightly greater than that predicted by theory. Also oscillations about the mean position appear in the experimental results. The difference to some extent between the experimentally-found error and the theoretical may be due to errors in measurement; the difference is small and could be accounted for partly by a small lag of the spark or by a small systematic error in setting the engine to the correct position in the static experiments. The latter is more probable; the brush had been set to that position at which it was just leaving the commutator segment. But sparking at the brush was apparent in the kinetic experiment, and, consequently, there would be a lag in the time of breaking of the current. This lag could not be calculated and was therefore neglected. Another possible source of error lay in the variable nature of the indicator paper; the spark did not always pass directly from the pencil to the drum, but took sometimes a longer path, choosing a part of the paper which offered less resistance. A purely chance error of this nature could only be eliminated by taking a sufficient number of diagrams and averaging or choosing that position which was repeated oftenest. The latter method was used, and the fact that a fair curve can be drawn through the experimental points so obtained is sufficient to warrant one in concluding that chance variations were eliminated.

The theoretical and experimental results show so close an agreement that it may be taken as demonstrated experimentally that the error deduced theoretically with the assumptions made is very near the average actual error, but that there are in addition secondary oscillation errors. These may, in certain cases, become very large. The fact that the cord has considerable inelastic stretch is possibly an important factor in damping them.

In order to obtain errors of measurable magnitude as long a cord as possible was used. This was necessary to obtain sufficient accuracy to check the theory. The theory, however, is equally applicable to other cases. All that is necessary is that the rate of elastic stretch and the corresponding inelastic strain of the drive should be known and their values substituted for the particular values in these experiments. The data can be readily obtained for any particular case by following the method used to obtain the results of Fig. 14. To improve the accuracy of the drum motion it is advisable to substitute a wire for the string. Necessity compels that a flexible wire be used, at least for that part where bending takes place. A wire of stranded copper was found to give good results; it, however, also showed a small amount of stretch and inelastic strain. The error in the drum motion when flexible wire was used was investigated experimentally; it was found to be small, Fig. 17; it would have been still smaller had a stiffer and less elastic wire been used in the straight parts of the length of the drive. In slow-speed engines inertia becomes less important and long diagrams become possible, with consequent diminution in the percentage error. Some experiments were made with short springs in the length of the driving wire. The results are of interest in that they show the presence of very large oscillations. The errors in the motion were of course very large, but there was nothing in the appearance of any one set of diagrams, unless they were compared with another set, which could enable one to detect the presence of oscillations or errors of any kind. The results are shown in Fig. 17, the ordinates of which are the same as those of Fig. 16.

(To be continued.)

THE OXYACETYLENE PROCESS OF WELDING AND CUTTING METALS.*

BY M. S. PLUMLEY.

IN the oxyacetylene process there are two recognised systems of generating the acetylene used—the high and low-pressure schemes. The low-pressure system delivers acetylene directly from the generator to the blowpipe under a pressure of a few ounces only. With this system a uniform pressure is maintained at all times, something which is an absolutely essential requirement. The high-pressure system delivers acetylene to the blowpipe under a pressure of more than 1lb. per square inch from a generator operating under 15lbs. or by acetylene stored in steel tanks; a diaphragm reducer is used. This system gives excellent results, especially for emergency work, where portability is essential.

Both systems have their advantages under certain conditions. The low-pressure system, however, is more generally recognised as completely fulfilling the multitude of problems that the process is called upon to solve in metal-working shops and foundries. With either, two parts of iron, steel, brass, copper, bronze, aluminium, platinum, and other metals may be welded by fusion and without subsequent compression. Temperatures ranging from 6,000° to 6,500° Fah. are available in small spaces. This process is the most economical method of cutting iron and steel.

The practicability of the oxyacetylene welding and cutting process has been thoroughly established by successful use under ordinary every-day working conditions in thousands of plants. The commercial possibilities of the process are being rapidly extended, since many of the largest engineering concerns throughout the world have adopted and are studying the process. New applications are being discovered daily. Many operations, which a few years ago were considered impossible or difficult of accomplishment, are being carried on to-day as a matter of ordinary shop practice.

In considering either the theoretical or practical applications of the oxyacetylene process, we must bear in mind the inherent characteristics of the metals upon which we work. Due allowance must be made for expansion and contraction in every stage of the manufacture of iron and steel. On the other hand, some metals, such as aluminium, brass, copper, &c., oxidise very rapidly at certain temperatures.

Failures which in the past have been attributed to the oxyacetylene process are almost without exception traceable to two causes: first, poor equipment (including generators, torches, and other accessories); and, second, lack of intelli-

* Abstract of paper presented before the annual convention of the American Association of Iron and Steel Electrical Engineers.

gent handling by the operator. It must not be inferred from this that the process is either extremely difficult or that it requires more than an ordinary intelligent operator to secure successful results—quite the contrary.

There are two methods of making autogenous welds. The first, suitable for thin plates, requires that the edges be brought into perfect contact. They are then fused together without the use of additional material. The second, used for thick plates, consists of fusing into a groove formed by the bevelled plate edges material similar to that in the plate. The thickness generally given as a dividing line between the two methods is ¼in.

The claim of 100 per cent. efficiency for a weld is not made, even by the most enthusiastic, 95 per cent. being about as high as may be obtained provided the weld to be tested has the same thickness as the original piece. In many cases the tensile strength and efficiency of the weld is increased by hammering lightly while at the proper temperature and subsequently annealing the piece. The operator of the oxyacetylene blowpipe may at will build up his weld by means of a piece of steel or iron wire which is fused in the flame so that the section at the weld is greater than the section at any other part of the material on which he is working. In this way even still greater efficiency is gained.

The natural contraction and expansion of steel when subjected to the necessary welding heat has been readily provided for wherever careful and intelligent thought has been applied to the problem at hand. For instance, not long ago an operator tried to weld a new half-side sheet in a locomotive firebox by putting the sheet in its correct position, fastening it securely with bolts, then applying the blowpipe to the longitudinal seam to be welded. The result was that upon applying the heat to the rigid plates expansion set in and, as the plates were not free to move, there was an upsetting of the metal. Upon subsequent cooling and contraction the plates were left under stress.

That operator did not apply what he already knew perfectly well about the action of metals when subjected to high temperatures. The job was later done in an intelligent manner with perfect success as follows: The edges which were to be welded were separated. Under the effect of the heat they gradually drew together as the weld progressed along the longitudinal seam. Being free to move at will in this way under the force of expansion and contraction, no strains were left in the finished work.

It is interesting to note in this connection that a ½in. plate will draw together at the rate of ⅜in. per foot. A simple and efficient method of taking care of expansion and contraction in cases where plates are not movable is to overcome the tendency to internal strain by the general application of heat in the vicinity of the weld or by providing corrugations or boxed places in the plates which tend to bend more or pull straight under the action of these natural forces.

The welding and cutting of steel-plate work can be done with great economy. Upon the introduction of the process, many operations could not be economically carried out because of the high cost of oxygen, but it is now possible to obtain oxygen at such a reasonable rate that a welded joint may be made in steel plate at a lower cost than a riveted joint, provided both are to be absolutely tight. The oxyacetylene cutting blowpipe since its adoption has had no competitor in this branch of the metal-working industry. A 1in. steel plate can be cut at the rate of 1ft. per minute, at a cost not exceeding 5d. per foot. A clean narrow slot can be cut through plates 12in. in thickness and over. In fact, this is about the only possible way of working on a plate or slabs of special steel. The speed at which this work can be done is very high, varying from 65ft. per hour for metal ¼in. thick to 5ft. per hour for 12in. thickness. The cost varies from 1d. per foot in ¼in. plates to 14s. per foot run in 12in. slabs

In the steel foundry the process, both for welding and cutting, has been accepted from the start. Enormous savings are possible in reclaiming defective castings of all sizes. The castings in many cases may have slight blow-holes or cold shuts, affecting only their appearance, or they may be defective in such places as to render them entirely unserviceable. In either case the welding blowpipe is used to make the defective casting perfect. Recently, in one of the large foundries, a cast-steel pinion weighing 4,100lbs. was defective when taken out of the moulds. New teeth were built on and after the casting was machined no trace of the weld could be discovered. It is sometimes well to preheat steel castings in the vicinity of the weld, thereby reducing the cost of that particular operation. However, this preheating process is not always applied.

The cutting blowpipe is a valuable instrument in the steel foundry for removing sprues, risers, and gates from steel castings. This work can be performed at one-half the cost of sawing. This statement takes into consideration the fact that it is not necessary to set large heavy castings at the saw and change their position for each separate riser. A vast amount of time is saved by being able to bring to these heavy castings the necessary equipment, which can be operated to cut from any position whatever. In one particular case, risers measuring 4in. by 8in. were cut from a cast-steel gear in 1½ minutes each. Manganese steel castings, when containing from 6 to 18 per cent. manganese, are so hard that it is impossible to cut them with steel tools. For such work the oxyacetylene blowpipe is the only method available.

The oxyacetylene welding blowpipe, as applied to the factory of the pressed-steel speciality maker, has made remarkable progress from both the standpoint of efficiency and economy. For the manufacture of metallic furniture it is indispensable. Joints can be made which are absolutely impossible to detect after the work is finished, and the blowpipe is the only device which can be used to accomplish such satisfactory results. In the manufacture of pressed-steel products the natural tendency of the metal to expansion and contraction has been very readily taken care of. Jigs are used to hold the light sheet metal in a very rigid position, so that when the weld is finished there is no evidence of buckling or warping. The possibilities of the process in this class of work have been largely extended by the introduction of automatic welding machines, of which there are already a number in very successful use.

With an automatic welding machine we are able to weld sheet metal of thicknesses varying from No. 26 gauge to ¼in. This is done in most instances without the addition of the filling material such as is used on heavy metal. Such welding can be done either by feeding the blowpipe to the work or feeding the work to the blowpipe, the most advisable method relying entirely upon the class of work at hand. The automatic welding machine, as its names indicates, eliminates the item of labour almost completely. A vast amount of steel tubing is being produced abroad by automatic welding.

In the forge shop, the oxyacetylene process has been permanently adopted in every instance where it has been introduced, as its possibilities and accomplishments are here practically unlimited. Forgings frequently develop very serious defects known as cold shuts. Before the introduction of the oxyacetylene process these defective forgings were only of scrap value, as there was no suitable method at hand to reclaim them. Now, however, they are very readily welded at a low cost. In welding this class of work, the most satisfactory results for every practical use are obtained when a soft Norway iron is fused into the defect as a filling material.

The cutting blowpipe has been found indispensable in the forge shop for such work as slotting engine connection rods, crank shafts, side rods, &c. In a connecting rod 6ft. 4in. long, 13in. across the face, and 6in. thick, a slot was recently cut 7in. wide by 9½in. long in 15 minutes. Eight hours time would have been required for the old method of drilling and chipping out the same slot. This operation is typical of hundreds that might be instanced to show that from the standpoint of economy the cutting blowpipe cannot be equalled.

When we speak of the oxyacetylene process as applied to structural-steel work we consider it chiefly from the standpoint of cutting. However, the welding blowpipe is very useful for filling up misdrilled bolt holes, which brings more strength to the structural part than it would have if, as has been the practice before the introduction of the process, the holes were allowed to remain. The cutting blowpipe which, since its use in removing the wreck of the Quebec Bridge, has been used for such work to the exclusion of all other methods, was employed extensively in raising the wreck of the old United States battle-ship "Maine."

In the machine shop, the process has become recognised as a necessary part of general shop equipment, as there is a continual demand for its use. While well adapted to work in all classes of metal, it is here most frequently applied to grey iron. In all machine shops, workmen continually make mistakes, such as cutting away too much metal from the piece on

which they are working, drilling holes in the wrong place, &c. Such errors generally mean throwing away the piece altogether, although in some cases there are methods of making repairs. This process has been found most satisfactory in reclaiming such parts, especially since neither the original mistake nor the weld itself can be detected after the surface has been machined or ground. The blowpipe can be also very successfully applied to the repair of broken machine parts; even large engine bedplates, punch press, lathe, and planer frames, &c., are being successfully mended.

As it is not possible to cut cast iron with the blowpipe, because of the high percentage of uncombined carbon and silicon, which will not oxidise even under the highest temperature, the oxyacetylene process as applied to operations in this branch of industry is restricted to welding alone. It might be well to state here that the cutting process is entirely a chemical action, which will not be successful on any metal which does not readily oxidise after it reaches a temperature of from 1,500° to 2,000° Fah.

The flame of the welding blowpipe has no tendency to appreciably change the chemical contents of grey iron. However, difficulty was at one time met in welding this metal on account of the weld tending to be porous after it was finished. We have overcome this difficulty successfully by adding a suitable flux containing principally borax, which brings the fusion temperature of the iron to a slightly lower degree than would otherwise be the case, and gives a more homogeneous weld of the proper texture when the cast iron fuses together.

In welding cast iron it has been found good practice to use a "filling-in" rod, which is fused to the original material being welded. By experiment it has been demonstrated that a cast-iron rod containing about 3 per cent. silicon gives the most satisfactory results. This high percentage of silicon, through its influence on the carbon of the iron, reduces the hardness of the weld considerably, so that it may be easily machined.

The contraction and expansion of grey iron is taken care of by preheating and annealing, the value of which, with this class of work, cannot be too strongly emphasized. Preheating the whole part to be welded to a temperature of about 1,000° to 1,500° Fah. more evenly distributes the expansion throughout the entire casting, preventing an unequal strain in any part. This same principle applies after the weld has been finished, annealing quickly bringing the entire casting up to an even temperature, so that when it cools the contraction takes place uniformly throughout the whole structure. Care must be taken, of course, while preheating and annealing, to avoid warping the casting. The most satisfactory and economical method of preheating and annealing large iron castings is with charcoal and compressed air, principally because the casting can be left on the fire while the welding is being done. For small castings, probably the most satisfactory method is with a burner, using oil and compressed air.

In cases of defective iron castings it is perfectly safe to assert that provided a blow-hole, crack, or other defect can be repaired in 15 minutes, and provided the casting weighs more than 50lbs., welding is the most economical way of handling it. This is a fair working formula. Only in the case of very small castings, in most instances, will it be found the most economical procedure to throw it back into the cupola.

With all metals which tend to oxidise readily at high temperatures, a flame should be used having a slight excess of acetylene, and using a smaller amount of oxygen than is required for doing the same thickness of work in steel. This action reduces the temperature of the flame and gives the operator better control of the molten metal. The amount of either acetylene or oxygen used in the blowpipe may be instantly regulated so that any desired quality of flame may be produced, either reducing, neutral, or oxidising in character, depending upon the class of work to be done. In this one respect alone, the process demonstrates its flexibility and adaptability to all classes of work.

In welding aluminium it is customary to counteract its natural tendency to oxidation by using a flux which breaks down the oxide and prevents oxidation of the metal when under fusion. A mixture of lithium, potassium, and sodium chlorides performs this function with entire success, and is now used in all cases. As with cast iron, the preheating and annealing process, already described, effectively prevents undue expansion and contraction. In some cases cold applications, placed around the part to be welded, produce the same results by preventing expansion from extending any distance through the structure. Aluminium being more ductile than cast iron, only a very slight stress will be left in the vicinity of the weld, even if not subsequently annealed. Defective aluminium castings of all kinds can be successfully repaired by this process.

The welding of sheet aluminium is being most extensively used in the manufacture of kitchen utensils, for which work it has no substitute. The welding of aluminium is now a very important branch of the industry, especially in the brewing industries, where it is largely supplanting enamelled ware. In welding sheet aluminium, as with castings, the fluxes and reducing flame overcome the tendency of the metal to oxidise.

Results from welding rolled brass sheets have so far been satisfactory, even in view of their high zinc content (20 per cent. to 40 per cent.), which oxidises at a low temperature. Fluxes consisting principally of borax are used with the reducing flame described above. When the zinc forms into an oxide, it comes out of the alloy in the form of a white cloud. In welding brass castings, a manganese-bronze alloy rod is generally used for a filling substance. This makes a good, strong, homogeneous weld and answers all practical purposes. In view of the value of these castings the welding process can generally be accomplished with a wide margin of profit, as it costs no more to weld them than it does grey iron or steel castings.

In the welding of copper the tendency to oxidise is taken care of, in addition to using the reducing flame, by covering the surface of the plate with a mixture of potassium phosphate and potassium carbonate to a depth of about ½in. and 2in. wide on each side of the seam. Upon the application of the flame, the mixture will melt and form a glaze over the surface of the metal, preventing oxidation and assuring good work. In welding copper plates it is best to use, as a filling material, strips of the original sheets, although the manganese-bronze alloy rods used in welding brass also give very satisfactory results.

In conclusion, it is well to mention three important factors upon which the success of the oxyacetylene process depends—oxygen, acetylene, and competent operators. When the process was first introduced no adequate supply of oxygen was available, and this indeed was a serious drawback. Oxygen was generated chemically from potassium chlorate at a very high cost and with a high percentage of impurities. This not only prohibited the process in many cases from the standpoint of economy, but also gave poor results on all classes of work because of the chemical effects of the flame. After the introduction of the liquid-air process for the manufacture of oxygen, the gas was produced with a high degree of purity and at a low cost.

Acetylene can be had in convenient form to meet practically every condition demanded by any working problem. It is usually made in "carbide-to-water" type generators, where small quantities of calcium carbide are added to large quantities of water (1lb. of carbide to 1 gall. of water), ensuring cool and safe generation. Generators may be had which in design and construction meet all of the requirements of the proper standards of safety set by the insurance interests. Calcium carbide may be obtained at exceedingly low prices.

The only condition demanded by the oxyacetylene process which is not met by stationary acetylene generators is where the object to be handled cannot be brought to the plant, such as in wrecking bridges or in structural work and in emergency welding, repair work, &c. In such cases there may be substituted acetylene stored in steel tanks filled with acetone, a liquid hydrocarbon which has the property of dissolving 25 times its own volume of acetylene for every atmosphere of pressure. By compressing the gas up to about 10 atmospheres a large volume of the gas is obtained in a very small space. These tanks are easily portable.

Labour has had a great deal to do so far with the accomplishments of the process, and will have a most important bearing on its future developments. Intelligent workmen have naturally taken a liking to this class of work and are very much interested in it. Large numbers are becoming daily more and more familiar with the most effective and economical operation of the blowpipe.

British Foundrymen's Association.—A meeting of the Lancashire Branch will be held to-morrow, February 1st, at the School of Technology, Manchester, when Mr. G. Barnes will open a discussion by reading a short paper on "Cores and Core Sand Mixtures."

COMPRESSED AIR IN MINES.

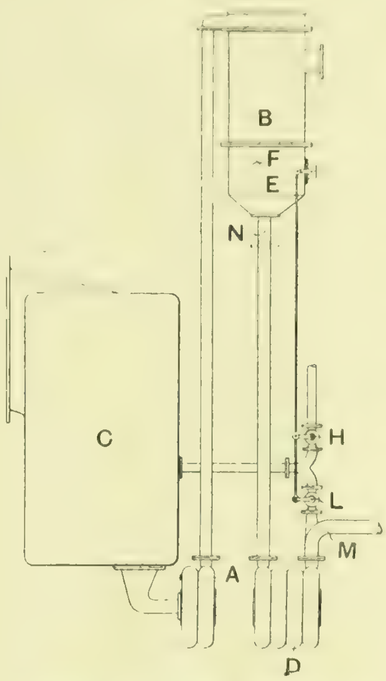
At a recent meeting of the Midland Institute of Mining, Civil, and Mechanical Engineers held at Leeds, a paper on "The Generation and Use of Compressed Air in Mines" was read by Mr. G. Blake Walker. The author directed attention to the manner in which compressed air had been brought to the front in recent years, more particularly for rock drills in mining and tunnelling work. There had also been witnessed the wide adaptation of electricity to mining operations, and the introduction of air compressors driven by electric motors. The extended use of coal-cutting machinery in recent years, and the limitation of the use of electricity in coal mines consequent on the provisions of the Coal Mines Act of 1911, had also brought about an increased demand for air compressors. Even with the most modern compressors, however, it was not possible to transmit air with the same economy as the electric current, and in practice the loss from leakage was a great deal more in the former than in the latter system. Losses in air compression and transmission were due chiefly to two causes—friction, and the loss of heat in the air from the moment of compression. In all compressors there was loss through drawing in the air through valve spaces, and expelling it through the outlet valves. Its whole course was then one of friction through pipes (often too small in diameter), and it finally had to overcome much friction in the valves and cylinders of the motor. Air could be used expansively, but not to the same extent as steam, and the essential difference was due to the heat losses in compression and expansion.

It was when the actual practical results obtained in return for the cost of producing compressed air were estimated that disappointment was felt at obtaining so poor a return for the expenditure. The practical fact remained that with ordinary dry compressors fitted with jacket water-coolers there was usually a loss of 25 per cent. by the time the air entered into the receiver. This included clearance losses, and the actual amount of the loss varied according to the superiority or inferiority of the cylinder and valve design. The loss in the motors actuated by the compressed air was quite as much as, or greater than, it was in the generator. In the one case heat was given off by compression; in the other, cold was produced on expansion. It happened frequently that the air actually converted into work underground was only 30 per cent. of the energy created by the steam engine. In such a case 25 per cent. might be due to compressor losses, 25 per cent. to motor losses, and the balance to friction in the air mains and leakages. This was where electric power showed itself more economical than compressed air, because the losses in the generator, in the conductor, and in the motor were all much less. Where, however, electric power was not permissible, compressed air, if somewhat more costly, became indispensable. Where the units were small and dispersed throughout a mine, it had been attempted to distribute these losses by installing small electrically-driven air compressors as near as possible to the places where air power was required. This was particularly the case with air for driving rock drills. The system was less cumbrous and more convenient, but he questioned whether the actual power economy was much greater than with direct air transmission.

The small portable air compressors could scarcely, by the nature of the case, be as efficient and economical as larger compressors. There were the motor losses, the gearing or belt drive, and the drop in current to allow for; and these little compressors must have some supervision, as well as maintenance and stores. When all come to be reckoned out, the balance in favour of small underground compressors could not be large. At Wharncliffe Silkstone Colliery, a modern two-stage compressor placed underground, driven by a 70 h.p. motor, was insufficient to drive two coal-cutting machines, which required about 25 h.p. each. It would just drive one coal-cutting machine and one face conveyer, the latter requiring 8 h.p.

MORISON'S APPARATUS FOR HEATING AND PUMPING BOILER FEED WATER.

We illustrate herewith a design of apparatus for heating and pumping boiler feed water, the invention of Mr. D. B. Morison, Hartlepool Engine Works, Hartlepool. The object of the arrangement is to obtain a high efficiency of such apparatus under variable conditions of working. For this purpose the rotary pump A, removing the water of condensation from the condenser C, discharges into an elevated heater B preferably of the spray type, but which may be of any other direct contact or surface contact type, and in which the water is heated by exhaust or low-pressure steam, the discharge from the heater being connected to the inlet end of the multi-stage rotary feed pump D, which discharges the heated water to the boilers. The elevated heater B is provided with a water reservoir E containing a float F which operates a valve H through which the supplementary feed water may be delivered into the system, the same float F also operating another valve L connected with the discharge pipe M from the multi-stage feed pump D to the boiler. The arrangement is such that when there is a deficiency in the supply of feed water and the water level in the reservoir E of the heater B is reduced below the normal, the float F, by falling, opens the supplementary feed water supply valve H and additional water is delivered into the system, preferably into the condenser C; or alternatively, if at any time the supply of feed water is greater than is required for the boilers and the level in the water reservoir rises above the normal level, the float opens the valve L connected to the discharge pipe M and water is by-passed into the condenser, through a spraying device, so that it is discharged over tubes, or elsewhere, and becomes reduced in temperature before re-entering the pumping system, whereby steam in the heater B is continuously condensed and water continues to flow through the feed pump D in sufficient quantity to prevent it from being unduly heated therein. The valves H and L may, if desired, be placed in the reservoir E, so that should there be any water leakage such water will pass into the system. The float F may also control a valve N in the discharge pipe from the heater, as represented by the dotted lines, for the purpose of throttling the flow of water to the feed pump D should the water level in the reservoir E fall below a predetermined limit. In this apparatus the working of the pumps being maintained, they are continuously supplied with a sufficiency of water, irrespective of the amount of feed water delivered into the boilers, and facilities are afforded for the continuous condensation of steam in the heater and for the de-aeration of the heated water.



Morison's Apparatus for Heating and Pumping Boiler Feed Water.

Sequel to a Boiler Explosion.—At Hamilton Sheriff Court on Friday last an official of the Belhaven Company (Limited), of Allanton Foundry, Morningside, was charged with culpable homicide in connection with the boiler explosion at the foundry on July 10th last, when three lives were lost. In the charge it is alleged that accused, in breach of his duty, allowed a boiler which he knew to be defective to be used, in consequence of which defects the boiler exploded and three men were so seriously injured that they died on the same day. Accused declined to emit a declaration, and was committed for further examination. Later in the day he was liberated on bail of £30.

THE DESIGN AND CONSTRUCTION OF SHOP CRANES.*

BY FRANK W. SUFFIELD, A.M.I.MECH.E.

It is my purpose to deal chiefly with the general design of cranes and to exclude the motive appliances with the exception perhaps of treating them in abstract. It will perhaps be interesting to consider first of all a few very early applications of mechanism to lift weights which may have formed the original ideas of the crane. It is thought that the first idea of a crane suggested itself when lifting broken off branches of trees from a river by the means of a rope of twisted thongs or fibres of bark thrown over the fork of an extended branch.

The windlass used on the British merchant vessel up till about the year 1769 appears to have advanced but little on the primitive form, with the exception of two points: (1) It did not rest on the side of the main deck, but in two strong timbers fixed on opposite sides of the main deck, a little behind the foremast, called "windlass bitts," and made in halves to enable an easy removal of the windlass, and (2) the windlass was furnished with pawls. The gin appears to have been the next development and used for raising water. The power was applied by a transverse beam, at each end of which a horse was yoked, the track being about 7 to 8 yards diam., so that the horse's force was not expended in an oblique direction. This enabled them to get a fair pull at the start. This of course was the origin of the term "horse-power."

The combination of ropes and rollers to gain mechanical power led to the contrivance of the "block." At first it was merely a piece of hard wood with a hole in it to reeve the rope through, such as are used to tighten the rigging of ships. These blocks had three holes, through which the rope passed, and then greased to reduce the friction. The round shape of the block and the position of the three holes resembled a human skull, or death's head, hence the word "dead-eye." In blocks constantly used, the friction and rigidity of the ropes caused so great a loss of power that it led to the addition of a roller or sheave in the block itself, which with other added improvements brought up the present crane blocks to their existing state of comparative perfection. The application of these early devices of mechanism were developed as they were applied to workshop and practical use.

The method of combining the advantages of the derrick with those of the crane was patented by a Mr. Henderson. The jib of this crane was fitted with a joist at the foot and had a chain instead of a tension bar attached to it at the top, so that the inclination of the jib and of course the radius could be varied as required. A similar design was used in stone quarries, but Henderson introduced a parabolic barrel, similar to the fusee of a watch, upon which the chain winds as it raises the jib and the barrel decreases in diameter as the jib approaches the horizontal line, so that the power to raise or lower the jib is equalised at all times.

In the construction of all machinery it is seldom, if ever, that complete fitness to requirements is attained until competition simplifies the design, and in no instance has this been more apparent than in the first cranes, which were chiefly applied to wharfs and quays. Those in the early part of the 18th century were made rude and clumsy, the design being borrowed from the Dutch, many of them worked by a man walking in the wheel. To lower the load the man walked backwards, a pole was suspended from the axle for the man to hold on to in case the weight overbalanced the man lowering it and thus preventing his being hurled round in the wheel.

The first improvement on these primitive cranes seems to have been to do away with the man in the wheel, which was reduced in size, and was fixed upon the external part of the jib. The next advance seems to have been the shipwright's crane. The general form appears to have remained, with the exception of the material of which the jibs were made, then of wood and cast-iron ends, afterwards of cast iron, and now built up sections.

One of the earliest examples of travelling cranes was designed by Rennie for the mahogany sheds at the West Indian Docks. Joseph Glynn in his book says, "A kind of railway was constructed in the roof upon parallel frames of timber extending across the building, and upon this a carriage travels from side to side of the house." Then followed the movement of the carriage from end to end of the building. Another early idea of travelling crane was the old bridge or "A" frame crane used in timber yards, entirely made of timber. The carriage was moved from one side of the bearer to the other by an endless chain passing over wheels on the crab and each end attached to winches fixed on each "A" frame. To raise the load the chain was wound on both winches.

The first successful attempt to work detached cranes by mechanical power, and without manual labour, appears to have been made by a Mr. Hague, of London, by means of air pumps worked by steam power. The next was a steam cylinder attached to the crane.

The first hydraulic crane was erected on the quay of Newcastle-on-Tyne. It was designed by Sir William Armstrong. The tanks or reservoirs were placed 100ft. above the level of the quay, three cylinders being placed under the ground; for ordinary weights the centre cylinder was used alone, and for extra weights it was assisted by the two external ones. A fourth cylinder was used to turn the crane round. A similar one was erected at Glasgow with a column of water 210ft. high and lifted 15 tons.

I have given you a résumé or retrospect, and I will now take up the modern and up-to-date methods. In designing a crane we must first know all the loads that it will be subjected to, both moving and fixed, and then proceed to set out the diagrams showing all the stresses to which it will be subjected. It has often been said sound judgment is a requisite of a successful designer, as no precise rules can ever be formulated to cover all cases as they arise in practice, and the judgment of the designer is called upon repeatedly to decide the correct proceeding when there is no precedent.

The jib cranes for workshops and foundries are as a rule hand-power cranes, but the introduction and development of the electric motor has perhaps influenced the design of no other auxiliary apparatus so much as that of the crane. There are some fixed jib cranes in railway shops driven by electric motors, but these are not general. There is also a pattern of jib crane which is very useful travelling on one rail, and called the walking crane, this being driven by electricity and designed on the same basis as the jib. The simplest application of electric motors to an overhead lifting and travelling application is when the carriage is suspended and run on the bottom flange of rolled steel joists, which are suspended in their turn in the shops over machines or work where lifting is required. They are termed runways and are largely used in small foundries and loading warehouses.

Overhead travelling cranes are probably in greater demand than other types on the market. Electrically driven, they are universally adopted for heavy loads, especially when continuous running and rapidity are required. The three-motor crane is the most efficient for modern workshop practice, but until recently the single-motor crane was considered the cheapest for engine-houses and places where only an occasional lift was required.

In selecting the given speed of the lifting load it should not be overlooked that the nominal load is seldom more than 20 per cent. of the full capacity of the crane. It is better, therefore, to consider the highest and safest speed at which this load can be worked, and then select a full load speed which will give the same foot-tonnage of work done. By the use of series-wound motors a variation above the rated speed of about 50 per cent. increase proportional to the load can be obtained. It is therefore unnecessary to use change gears on the main lift. On cranes, say, over 20 or 25 tons, where the full load is only occasionally handled, and the crane is used frequently for light loads, it is often economical to have an auxiliary barrel fitted on the crane, and worked by a separate motor with a capacity of 5 to 6 tons, and a speed of 20ft. to 40ft. per minute, the lift being one-fifth of the full capacity of the crane and the speed such as will give the same foot-tonnage as the main lift. It is never worth while having a change of gear to the cross traversing and travelling motors. The speeds are variable according to the work required to be done.

Just a few remarks about obtaining the horse-power for the motors. The lifting motor depends purely on the work done on the load and the power absorbed in the friction

* Abstract of paper read before the Birmingham Association of Mechanical Engineers, January 16th 1913.

of the gearing, journals, &c. It varies with the number of reductions and the type of gearing. A common rule in practice is to allow 10 foot tons of work done at the hook per brake horse-power, this being equivalent to a mechanical efficiency of about 66 per cent. This is very near for medium or large cranes, but for smaller sizes it allows a slightly larger motor than is really necessary, which is perhaps good, as it is the smaller cranes which are in more constant use. The power required for cross traversing and travelling must be sufficient to overcome the rolling and axle friction and the friction of the intermediate driving gear. For practical purposes resistances of 40lbs. to 50lbs. per ton for cross traversing, and 60lbs. to 70lbs. per ton for travelling are allowed for the best class of travelling cranes which have large diameter wheels and machine-cut gears.

I will now consider a few details of the framing and general details of the crabs. The difference in appearance is chiefly in the design of the crabs themselves. There has been a difference of opinion as to the best materials, some makers using cast-iron frames up to considerable sizes, but it is now almost universal to use a steel framing for all sizes. The chief idea in designing is to make all parts as accessible as possible for removals, repairs, and general attention, and to keep the structure as light as possible with stability. Some makers use steel plates either double or single, but these box up the motors and gearing too much, and perhaps, what is worse, necessitate solid bearings.

In designing the framing for crabs it is almost impossible to give definite calculations as general rules, but care must be taken that the stress limit does not exceed 5 tons per square inch, to avoid possible deflection or bending of shafts. In crabs for light cranes it is difficult to design a stiff enough frame without putting more material in than is required for actual strength. The running wheels and axles are the first to be considered, and the material from which they are made is important. For first-class work cast iron should not be used above 10 tons. Cast steel should be used. The wheels should be made as large as possible, in order to reduce the tractive resistance. The axles should be made as small as possible. The overhang from centre of bearing to centre of wheel should not exceed 5in., and the working strain should not exceed 5·5 tons per square inch. The length of the bearings should be so designed as not to give more than 900lbs. per square inch of projected area. They are usually of cast iron with brass bearings on the top. The most important part is the lubrication, and for crabs over 40 tons self-oiling ones should be adopted. Roller bearings are also sometimes adopted for these bearings for heavy cranes. Sometimes for very heavy crabs the axle bearings are put on both sides, which enable less width in bearings to be used, and the gearing can be more compactly arranged. One wheel on each side would require to be geared with this arrangement. The barrels are usually made of cast iron, and the rope grooves turned in to suit the diameter of rope to be used. The following table gives the approximate sizes of the steel ropes suitable for this work.

Loads in Tons.	No. of Ropes.	Circum. in In.
3	2	1¾
5	2	2¼
7·5	4	4
10	4	2¼
15	4	2¾
20	4	3¼
25	4	3½
30	4	4
40	4	4½

The usual factor of safety is 8, which allows a good margin if a few strands should break. The life of a rope depends largely on the diameter of the barrel and the number of pulleys it passes round. Some makers recommend 6½ times the circumference of the rope. This appears suitable for ropes under 3½in. circumference, but above this 5½ to 6 should be quite large enough for the barrel. An important point is the spacing of the ropes on the barrel, *i.e.*, the centres of the grooves. For all ropes up to 4in. circumference ⅛in. should be left between the sides of the ropes, but above that size $\frac{3}{16}$in. if possible. This is to allow for the flattening of the ropes while under load, and to avoid their grinding together. The usual practice is to allow the lift to be taken in the centre of the barrel to distribute the load more evenly on the girders. From 7 to 50 tons the load should be lifted on four parts of the rope, *i.e.*, two parts in right and left hand grooves on the barrel, the other end passing round a pulley. This pulley need not exceed twice the circumference of the rope.

For cranes up to three tons the load should be lifted in a single pull of rope, for 5, 6, and 7 tons with two, one end being on the barrel; four ropes up to 50 tons, six to 75 tons, and so on. It is not so important to lift centrally with small cranes as the load on the girders can never exceed the strength of the material used, and it always must be in excess of requirements. The thickness of metal in the barrel must be considered, and the stress of bending must not exceed 7·5 tons per square inch, this giving ample strength. The barrel shaft must be considered in the same way as other shafts, also the bearings with the same bearing pressure.

Gearing is one of the most important parts of crane design. For heavy loads it is advisable to have cast iron for the barrel gear and pinion, because it is advisable to shroud the pinion, and the speed being low the loss due to friction is not worth considering. Rawhide motor pinions are found to be suitable for the first reduction up to 20 tons, gearing into cast iron. These run very smoothly, and do not require lubricating. Above 20 tons the motor pinions ought to be machined steel, running with cast iron, or steel wheels in an oil bath. The barrel wheel and pinion up to 20-ton cranes are made in cast iron, but above this cast steel is better, and in all cases above 7 tons the pinions must be shrouded. For cranes above 20 tons it is good practice to make all the pinions of steel. Altogether the sizes of the pinions should be as small as possible; no pinion, however, should have less than 12 teeth.

In crane work, as in all other gearing, the strength of the teeth is most important, and the question of the stress to which these are subjected is very variable in actual practice. The average ultimate strength of cast iron and cast steel subject to bending (as in a tooth) is 18 and 30 tons respectively. Due to the nature of the metals and the methods of manufacture, one would be justified in allowing a factor of safety of 8 for cast iron and 6 for cast steel for slow running. I do not purpose to go into the detail of the design of teeth. Using reliable formula such as Prof. Unwin's would be quite satisfactory. Involute teeth with radial flanks, which give a short tooth with a broad root, are mostly used because of their great strength. Some makers shroud the barrel gear and pinion to the pitch line, but if the calculations are taken at this point the object is defeated. The chief value of shrouding is to minimise the tendency of the teeth breaking across the corners, especially cast-iron ones. Double helical gears are sometimes used for cranes, say over 30 tons on the barrel and pinion.

Electrically-driven cranes must be fitted with effective brakes, and of these there are two kinds—magnetic and mechanical. Magnetic brakes are generally ordinary strap or clamp brakes, which are held off by a magnet or solenoid connected with the motor, so that when the current is taken off the brake comes into action. To avoid a too rapid action, the solenoid forms in itself a dashpot, the air being throttled in a small hole at the top of the body. It must be sufficiently strong to hold the full load in the event of the mechanical brake failing. When both brakes are used the solenoid is almost solely used for stopping the motor rapidly, and as it will run both ways the cramp type of brake is found to be the most suitable. Brake pulleys on the motors should be as large as possible, but the peripheral speed should not exceed 2,000ft. to 2,500ft. per minute. Automatic mechanical brakes vary in design.

We now come to the consideration of the main girders. The selection of the type to apply for a given crane is an important point, since the general efficiency of the crane is affected by this question. Further, if it is to be a competitive machine economy has also to be taken into consideration. A great variation of opinion exists among makers as to the basis of working stress on which they design their girders. Frequently firms whose designs are the most expensive and elaborate, work on 4 tons to the square inch, whereas others, whose aim is to meet the demand for the cheapest crane, work on 7·5 tons per square inch, or even higher. My opinion is that for a good sound result 5 to

$5\frac{1}{2}$ tons per square inch should be the limit, and this will cover all contingencies and avoid all undue deflection in the shafts, &c. There are four principal types of girders: (1) Rolled steel joists; (2) box plate girders; (3) single-web plate girder; (4) braced or lattice girders.

The rolled steel joist is, of course, the simplest type of girder, and is frequently used for spans up to 40ft. for light loads, and 30ft. span up to, say, 20 tons. For cranes above 15 tons in spans up to 65ft. the box girders are considered excellent. One disadvantage is that they cannot be got at for painting inside. The sections and proportions required for such loads generally ensure the girder being stiff enough without causing any lateral distortion. For cranes up to 15 tons, say up to 40ft. span, where rolled steel joists are not stiff enough, the single web plate girder can be made economically with one or two provisions. The speed must not be excessive, and platform girders should be added and braced horizontally to the main girder. For cranes up to and including 4 tons, above 40ft. and all 65ft. or 75ft. spans, braced girders are the most economical. They are cheaper to make and less in weight, and consequently use less power. The most important thing is to adopt the right kind of bracing for each specific case. From the points of cost, weight, and convenience the best is the Warren type. Where rolling load is large and heavy in proportion to the structural load, the double or partly double lattice girder is adopted.

The first step of calculation for crane girders is to obtain the bending moment in the ordinary way. This must include the forces due to (1) rolling load, (2) weight of crabs, (3) structural load, *i.e.*, weight of girder, platform, and cross shaft; (4) if the driving motor is in the centre this must be added. I do not propose to consider impact forces in any one case, as these are often neglected by crane builders, although, in my opinion, something should be added, especially for high-speed cranes.

If the crab is symmetrically built the rolling load may be considered as being divided equally on the four wheels; consequently it shortens the effective span of the girder by the distance of the centres of these wheels. This bending moment of the rolling load is obtained by multiplying the reaction at either support by the distance from that support to the centre of the crab wheel nearest the support.

The bending moment due to the structural load, in the usual way for a distributed load M.B. $= \frac{W.L.}{8}$ and that of the driving motor as a concentrated load M.B. $= \frac{W.L.}{4}$

These can be obtained by diagrams, but can be developed as follows, assuming a crane of 25 tons, 50ft. span, with a crab of 5 tons carried on a wheel base of 5ft., and the girder, platform, &c., at 5 tons, and the travelling motor $\frac{3}{4}$-ton.

B.M. Rolling load = 270in. × 7·5 = 2,025in.-tons

$$\text{Structural} = \frac{5 \times 600}{8} = 375 \quad ,,$$

$$\text{Motor} = \frac{3 \times 600}{4 \times 4} = 112{\cdot}5 \quad ,,$$

Total 2,512·5 in-tons.

The next question is the depth. For crane work one-twelfth to one-sixteenth is usually allowed according to the size of the crane. For heavy loads it is more economical to increase the depth than to make the flanges heavy. We must first assume a suitable section now that we can decide the depth, allowance being made for rivets, say $\frac{1}{8}$in. larger than the diameter. We can then proceed to obtain the moment of inertia, which must be taken about the neutral axis, this being for rectangular symmetrical sections one-twelfth multiplied by the breadth, multiplied by the height cubed. The modulus of a symmetrical section is equal to the moment of inertia divided by the distance from the neutral axis to the extreme outer edge of the section, and this must be equal to the bending moment divided by the working stress.

The web plates should not be less than $\frac{1}{4}$in. thick under any circumstances to allow for deterioration, and for box girders these can be used up to 20 tons; $\frac{5}{16}$in. for 30 to 50 tons; and $\frac{3}{8}$in. above these loads. Whereas for single web girders $\frac{1}{4}$in. plates can be used for cranes up to 7 tons, $\frac{5}{16}$in. to 20 tons, and $\frac{3}{8}$in. above. These are only approximate, and require in some cases stiffeners, which are usually of T irons. They do not, however, require to be at such close centres as for bridge work. About 4ft. to 5ft. apart is all that is necessary in most cases, but it depends entirely on the size of the girder and the loading. It is quite unnecessary to have the full length of the girder the same depth, and it is usually made "fish-bellied" or the bottom flange made polygonal, the angles occurring where the stiffeners come.

For high-speed cranes we must consider lateral stresses, due to suddenly stopping the load. If we take the previous example, and assume it runs at 300ft. per minute, or 5ft. per second, under full load, the momentum of load and crab at full speed will be 11·5ft. tons. If I assume the crane travels 5ft. after the current has been cut off and the brake put on, the horizontal force on the two girders would be $\frac{11{\cdot}5}{5} = 2{\cdot}3$ft. tons, giving 1·15 tons per girder. To this must be added the distributed effort as well, which would equal about ·05 on the same formula. We must therefore see that the total lateral stress does not exceed 4 tons per square inch under these conditions, so as to avoid any possibility of distortion from the concentrated load. It is quite obvious that the girders might fail this way, and yet be amply strong to carry the load in the span, but the fixing of the platforms often assists very materially to overcome the difficulty.

In order to calculate the strength of the end carriages we must know the load of the crab at the extreme end, to which must be added the weight of the girders themselves. It is also necessary to fix the centre of the girders and the travelling wheels. The first depends upon the requirements of the crabs, and the second should be about one-fifth of the span. Channels are most convenient, or plates and angles. The wheels should be from 18in. to 30in. diam., according to the size of the crane, and of cast steel or cast iron with steel treads. The toothed wheel should be by preference bolted to the wheel, rather than keyed separately or cast in one piece. One of the greatest objections to the cheap crane is allowing these wheels to be bushed, and to run loose on the spindles, and this is one of the many bad features which are adopted to cheapen the cost. This is seldom noticed by buyers, who do not trouble to look into details or get anyone to assist them who may know.

The platforms may add to or detract from the appearance of a crane, and it is very largely a matter of opinion as to whether there shall be one, two, or none at all. For light cranes, when rolled steel joists are adopted for the main girders, four girders are used, and wood battens laid between the two outside girders. For light lattice or single web girders it is found cheapest to form light subsidiary girders and fix to main girders with diagonal bracing, so that this will increase the lateral stress. In some cases the top plate of the girder can be extended to form the platform of chequered plate, which practically strengthens the construction. When the crane girders are stiff enough brackets can be carried on the sides of them, and these must be designed to be uniform with the remainder of the work. Timber is usually used for this purpose on account of its cheapness and lightness. The cab is made of a very light construction, and suspended from the end of the main girders. It should be just large enough to contain the controller, switches, and for the driver to sit down. Lubrication is a very important point, and every facility must be made for fixing lubricators when oil baths are impossible.

Fatal Flywheel Burst.—One man was killed, and four others injured, as the result of the bursting of a big flywheel at the Clydesdale Iron and Steel Works, Moss End, Lanarkshire, on Saturday last. It appears that the men in No. 4 Mill were engaged in rolling some unusually heavy steel material when the flywheel burst, the main part flying through the roof of the structure and smashing the overhead steam pipes. One of the men was terribly scalded, and died on his way to the infirmary. Extensive damage was done to the mill.

AIR GAS AND ACETYLENE FOR LIGHTING PURPOSES.

Two interesting papers, one on petrol air gas by Mr. E. Scott Snell, and the other on acetylene by Mr. C. Hoddle, were presented at a recent meeting of the Illuminating Engineering Society.

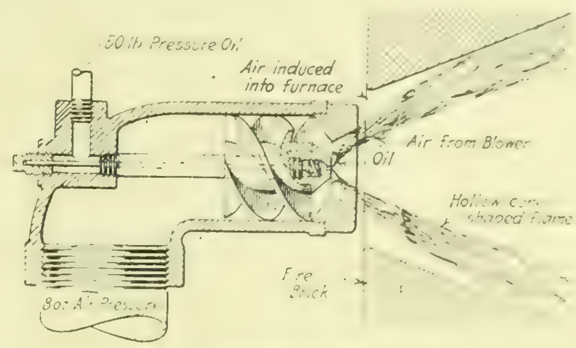
In the course of his paper, Mr. Scott Snell explained that petrol air gas consisted of air to which had been added a small percentage of petrol vapour. The mixture was generated by suitable machines, and subsequently forced through pipes in a similar way to coal gas. The pipes contained only a mixture of air and petrol vapour, and the percentage of the latter was invariably small (1½ to 6 per cent.). It could therefore be claimed to be quite safe when properly designed, for it would hardly be possible for a leakage of petrol air gas to give rise to serious danger, over 94 per cent. of the escape being pure air. On the other hand, petrol air gas was not a true gas, but only a mixture of certain volatile hydrocarbons with air, and some of these hydrocarbons might condense if a wrong mixture or an imperfectly designed form of plant were employed. Special burners, having nipple apertures much larger than those used for gas, were required. The fact that such a large proportion of air was taken into the burner through the pipes also rendered it possible to obtain at the comparatively low pressure of 1½in. conditions of combustion comparable with those obtained by high-pressure gas. The size of inverted mantle commonly used (the Bijou type) yielded a much more brilliant light than would be obtained with corresponding mantles with low-pressure coal gas. Some tests recently carried out at the County Works showed that some new mantles were giving 70 c.p. to 80 c.p., while others, which had been in use for some hundreds of hours, were still giving 48-50 c.p.

With regard to cost, claims varying from ½d. to 4d. per 1,000 c.p. hours were made. The price of light from petrol must be a function solely of the price and value of the spirit itself, and could not be influenced by the methods of its generation, provided that the apparatus worked efficiently. Prof. Vivian Lewes reported an efficiency of 5,000 c.p. hours per gallon, whereas Mr. O'Connor gave a test of about 6,500 c.p. hours per gallon. The author was present at a test giving 4,500 c.p. hours per gallon; whilst Mr. Strode issued a report which worked out at 6,000 with one burner, and 9,350 c.p. hours per gallon with another, both with rich gas. In some recent rough tests the candle-power of a burner with a new mantle, guaranteed to consume not more than one-ninetieth of a gallon an hour, gave a maximum reading of 70 c.p., which was equal to 6,300 c.p. hours per gallon. The average of all the foregoing figures was 6,800 c.p. hours per gallon. With petrol at 1s. 9d. net, this was equivalent to only 3·1d. per 1,000 c.p. hours. All these tests related to plants consuming light spirit. There would be a substantial pecuniary gain from the use of heavy petrol if the whole of the spirit were used for giving light, as in the case of a weight-driven plant using 0·680 fuel.

Mr. Hoddle, in his paper, said that with acetylene it was possible to obtain about 40 c.p. of a pure white light for a consumption of 1 cub. ft. of gas an hour, which, at the present price of calcium carbide, 13s. 6d. per cwt., was equal to about 7d. per 1,000 candle-hours. The light was quite constant, and could be used, if necessary, in burners giving only 10 c.p. In an ordinary house-lighting installation the burners took from ½ cub. ft. to 1 cub. ft., according to position; but the burner most generally in use took ½ cub. ft. an hour. The lights could, he claimed, be turned up or down and the illumination regulated much more perfectly than was possible when mantles were used. The cost of lighting an average country house by means of acetylene, assuming that such a house required 50 lights, giving a total candle-power of about 1,000 with two-thirds of the lights on, would amount to about 7d. an hour. If the majority of the lights were used on an average three hours a night, the yearly cost of carbide would be about £30. The total cost of installation, including fittings and piping, should not be more than £100. The generator installed would probably be of the twin type, which enabled one section to be used while the other was being recharged. The charge in the two generators would keep the lights going for eight hours, assuming that only two-thirds of the lights were going at once. One of the most useful purposes to which acetylene would shortly be put was, he said, the cinematograph. A mixture of acetylene and oxygen used on a special disc of ceria gave a light almost equal to the electric arc, the candle-power immediately opposite the incandescent disc being nearly 1,100.

STILZ OIL BURNER.

THE fuel-oil burner shown in the accompanying illustration, for which we are indebted to "Engineering News," has been designed and patented by Mr. H. B. Stilz, 1,938, N. Marvine Street, Philadelphia, Penn. A characteristic of many low-pressure oil burners has been their ineffective atomisation of the oil and a consequent low combustion efficiency. Therefore recourse has usually been made to high-pressure air or steam for atomising, but the general difficulty which seems to have been encountered here lies in the difficulty of thorough mixture of the oil particles with the proper amount of air on account of the high velocity of the former. The design shown, which atomises oil at high pressure with air under low pressure, comprises an inner nozzle through which oil is forced at 50lbs. pressure. At the end of the passageway in this nozzle is a small orifice, and within the passage is placed a spindle bearing a spiral fin, which is



STILZ OIL BURNER.

claimed to cause the oil on delivery to rotate and spread out in a cone-shaped film. Around the inner nozzle above mentioned is a casing through which air passes, and within this casing is a larger spindle also with a spiral fin, which it is claimed gives the air a whirling motion as it passes out. By the velocity of the air in a radial direction from the burner axis, a certain amount of suction seems to be produced which draws the oil particles into the current of air. This, it is claimed, results in the desired intimate mixture and atomisation. The shape of the issuing flame is controlled by the shape of the bell mouth of the outer orifice. It is reported that competitive tests, conducted in 1912, at the plant of the Link Belt Company in Nicetown, Pa., showed that this type of burner required only some 31 per cent. of the amount of fuel of high-pressure burners in use. Sizes have been made to give a capacity range of from under 1 gall. of oil per hour to over 400 galls.

METAL QUOTATIONS.

TUESDAY, JANUARY 28TH.

Aluminium ingot	95/- per cwt.
,, wire, according to sizes, &c. ......from	112/- ,,
,, sheets ,, ,, ... ,,	120/- ,,
Antimony ......£38/-/- to	£40/-/- per ton.
Brass, rolled	9½d. per lb.
,, tubes (brazed)	10¼d.
,, ,, (solid drawn)	8⅞d.
,, ,, wire	[illegible]d.
Copper, Standard	£68/12/6 per ton.
Iron, Cleveland	65/3 ,,
,, Scotch	71/3 ,,
Lead, English	£17/2/6 ,,
,, Foreign (soft)	£16/15/- ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/[illegible]/- per bottle
Silver	28[illegible]d. per oz.
Spelter	£26/5/- per ton.
Tin, block	£226/5/- ,,
Tin plates	15/- ,,
Zinc sheets (Silesian)	£29/7/6 ,,
,, (Stettin; Vieille Montagne)	£29/12/6 ,,

WORLD'S SUPPLY OF IRON ORE.

THE production and consumption of iron and steel in the United Kingdom and the principal foreign countries in 1911 are dealt with in a Board of Trade White Paper just published. The world's total output of iron ore in 1910 was about 145 million tons, but in 1911 though the figures are not yet available there would appear to have been a decrease owing to the falling off in the production of the United States from 56,890,000 tons to 40,990,000 tons. Germany produced 29,399,000 tons, its best total on record, and the United Kingdom 15,519,000, as against 15,226,000 in 1910 and 15,732,000 in 1907. Our greatest output was over 18 million tons in 1882. Third place was for the first time taken by France, which country, with a total of 16,127,000 tons, maintained the rapid advance which it has shown during recent years. Other large producers were Russia, Sweden, and Austria Hungary all registering an increase.

The iron ores used for smelting are of varying chemical composition, and occur in several different geological formations. They are also of different richness, the quantity of iron they yield ranging from as little as 20 per cent. to over 65 per cent. of their weight. A report on the extent of the iron ore resources of the world was presented at the Eleventh International Geological Congress at Stockholm in 1910, in which it was estimated that the total actual resources of iron ore existing in deposits that can at present be worked at an economic profit amounts to 22,408 million tons, representing 10,192 million tons of iron. This total would supply the requirements of the world for considerably less than two centuries, even were the present rate of output not exceeded on the average. The actual resources of the principal ore-producing countries are estimated to be, in the United States, 4,258 million tons, the equivalent in metallic iron being 2,305 million tons; in Germany and Luxemburg, 3,878 million tons, estimated to yield 1,360 million tons of metallic iron; in the United Kingdom, 1,300 million tons, equal to 455 million tons of metal; in France, 3,300 million tons, equal to 1,140 million tons of metal; and in Spain, 711 million tons, equal to 349 million tons of metal.

In addition to these quantities the potential resources of the world not yet developed are estimated to amount to 123,377 million tons of ore, representing 53,136 million tons of iron. Further, very large supplies of iron ore are understood to exist in China, Canada, and other countries, but no definite information is at present available as to their extent. The actual resources of the United Kingdom are calculated at 455 million tons of iron, and the potential supplies at 10,830 million tons, including 9,500 tons of metal contained in clay-iron stone deposits in South Wales, Scotland, and elsewhere which are not yet workable.

The total world's production of pig iron in 1911 was about 63 million tons, the United States (23½ million), Germany (15½), and the United Kingdom (9¾), accounting for seven-ninths of the total. The following statement shows the output of pig iron in the first half-year of 1912, so far as particulars are available, compared with the output in the two previous half-years:

Country.	1911. First Half-year. Thousand Tons.	1911. Second Half-year. Thousand Tons.	1912. First Half-year. Thousand Tons.
United States	11,666	11,984	14,072
Germany	7,559	7,763	8,289
United Kingdom	5,111	4,608	3,606
France	2,159	2,277	2,307
Belgium	1,008	1,005	1,104

Particulars of the output of pig iron in other countries in the first half-year of 1912 are not available. The reduction in the output of the United Kingdom in the first half-year of 1912 was due to the stoppage of works owing to the dispute in the coal trade. The output of pig iron in the United States in the second half-year of 1912 is estimated at about 15,600,000 tons, that of Germany at about 9,277,000 tons, and that of Belgium at about 1,203,000 tons. Taking the average of the last five years, in the United Kingdom over 56 per cent. of the pig iron made was steel-making iron (hematite, basic pig, spiegeleisen, &c.), in France about 66 per cent., in the United States over 74 per cent., in Germany over 75 per cent., and in Belgium about 87 per cent. The combined output of steel in the United Kingdom, Germany, and the United States in 1911 exceeded 45 million tons, and the world's output might be estimated at between 59 and 60 million tons.

INDUSTRIAL AND TRADE NOTES.

South Wales Tinplate Trade.—The South Wales tinplate manufacturers have decided to hold a meeting at an early date to consider a proposal for restriction of output, having regard to the unsatisfactory condition of the trade. A leading manufacturer at Swansea said the trade was in a deplorable state, and if prices did not improve the masters would have no option but to stop.

United States Patents.—The annual report of the U.S. Commissioner of Patents for the fiscal year ended June 30th, 1912, shows that there were 69,236 applications for patents for inventions. The number of patents granted was 34,220. During the year 19,631 patents expired. During the past five years the number of patents granted annually has not varied to a substantial degree

The Recovery of Waste Products.—An invention recently perfected by Sir Oliver Lodge and his son, Mr. Lionel Lodge, has for its object to recover the metal from the fumes escaping from smelting works. These fumes are heavily laden with metals and acids of considerable commercial value. Sir Oliver Lodge has been working since 1884 on the machine, and it is claimed that over 90 per cent. of the metal which now escapes can be saved by its use. Exhaustive practical tests of its utility are being made in Birmingham and North Country metal works.

Lighting of Factories.—The Home Secretary has appointed a committee to enquire and report as to the conditions necessary for the adequate and suitable lighting (natural and artificial) of factories and workshops, having regard to the nature of the work carried on, the protection of the eyesight of the persons employed, and the various forms of illumination. The committee are: Dr. R. T. Glazebrook, C.B., F.R.S., Director of the National Physical Laboratory (chairman); Mr. Leon Gaster; Prof. Francis Gotch, D.Sc., F.R.S.; Mr. J. Herbert Parsons, M.B., D.Sc., F.R.C.S.; Mr. W. C. D. Whetham, F.R.S.; Sir Arthur Whitelegge, K.C.B., Chief Inspector of Factories. The secretaries of the committee are: Mr. D. R. Wilson, one of His Majesty's Inspectors of Factories; and Mr. C. C. Paterson, M.I.M.E., A.M.Inst.C.E., of the National Physical Laboratory.

Geared Turbine Steamer for India.—Messrs. A. & J. Inglis, Pointhouse, launched a few days ago the turbine steamer "Hardinge," the second of three sister ships which they are building for the South Indian Railway Company. The steamers, which have been designed for ferry service, have a length over all of about 260ft., a breadth of 38ft., and a depth to promenade decks of nearly 19ft. They will be rather less than 700 tons gross. The propelling machinery, constructed by the builders, consists of two sets of geared turbines of the latest Parsons type, one high-pressure and one low-pressure being coupled to each of the two shafts by means of machine-cut gears and each shaft driving one of the twin screws. The revolutions of the turbines will be about 3,500 per minute, which will give a high turbine efficiency. By means of the mechanical reducing gear the propellers will revolve at a much less speed—500 revs.—and so secure greater propulsive efficiency. The boilers are of the Yarrow type.

Canadian Trade.—The report of the Department of Trade and Commerce of the Dominion of Canada for the fiscal year ended March 31st, 1912, contains statistics of Canadian trade with France, Germany, the United Kingdom, and the United States. This shows that the value of the trade of Canada with the world has grown uninterruptedly since 1893. Her total imports and exports in that year were valued at $247,638,620, whereas in the last fiscal year they ran up to $874,637,794. From and to France the value of the trade last year was slightly less than in 1911, but since 1908 it has greatly increased. Trade with Germany has materially improved since 1910, but the total trade with France and Germany last year amounted only to $28,971,071, as compared with $269,045,844 in the trade with the United Kingdom. There was a big increase in the trade with the States. The imports and exports amounted last year to a total of $488,679,741.

Trade Circulars and Catalogues.—We have received from Messrs. Vicars, Ltd., of Sheffield and Westminster, a handsomely illustrated booklet of photo illustrations showing interior views of their works and installations of various kinds which they have supplied. There is no descriptive matter, but the views themselves testify to the wide range of work with which this eminent Sheffield firm is associated. Messrs. Wailes, Dove, & Co., Ltd., St. Nicholas Buildings, Newcastle-on-Tyne, the well-known makers of bitumistic enamels, cements, and coverings, send us a little pamphlet descriptive of the merits of their various preparations and of the varied uses to which they are put, especially in connection with shipping and civil engineering enterprises.—Messrs. Edwin A. Mansfield

and Co., 12, Beckenham Road, New Brighton, send us a circular descriptive of their system of locating underground pipes. Messrs. A. E. Reed & Co., Ltd. 11, Victoria Street, Westminster, send us an illustrated catalogue of elevating and conveying machinery and constructional steel work; and Messrs. W. A. Walber & Co., 38, Victoria Street, a list of their power hammers.

New Type of Diesel Engine.—The first of a new type of Diesel engine has recently been completed at the works of Messrs. William Doxford & Sons, Ltd., of Sunderland. The engine consists of a single cylinder unit, and is intended ultimately to form one of four or six similar units necessary to produce the power required to propel a 6,000 ton vessel. The cylinder is 19½in. diam., with a 37in. stroke. The engine when running on load at 130 revs. per minute, and driving its own scavenging pump and air-compressor, has given 300 b.h.p. for prolonged periods. The scavenging pump is driven by rocking levers from the cross head, and during recent trials the pressure of the scavenging air entering the cylinders did not exceed 2lbs., while the pump pressure was not greater than 4lbs. per square inch; four scavenging valves are used on the cylinder. Reversing is effected by turning the cam shaft through an angle of 30° to 40° relative to the crank shaft by means of a lever, the fuel and scavenging valve cams being thus set in their correct position for astern running. Two cams are provided for starting, one for astern and one for ahead running, placed side by side. The lever of the valve has two rollers, one of which is held off the cam and the other is dropped on it, according to the required direction of rotation. The fuel supply to the cylinders is controlled from the starting platform by operating on the suction valve of the vertical oil pump, and the governor simply controls the fuel admission. The arrangement of the cams and cam shaft is simple, and reversing has proved to be both rapid and positive.

Shipbuilding Output in 1912.—In their review of shipbuilding at home and abroad in 1912, Lloyd's Register point out that, exclusive of warships, 712 vessels of 1,738,514 tons gross (viz., 643 steamers of 1,720,957 tons and 69 sailing vessels of 17,557 tons) have been launched in the United Kingdom. The warships launched at both Government and private yards amount to 30 of 191,737 tons displacement. The total output of the United Kingdom for the year has, therefore, been 742 vessels of 1,930,251 tons. The amount of tonnage launched for abroad during 1912 was 415,519 tons, forming 23·9 per cent. of the total output, as compared with 22¼ per cent in 1911. The British Colonies have provided the largest amount of work. The number of large steamers launched in the United Kingdom during 1912 has greatly exceeded the average of recent years. The returns show that during this period 69 vessels of 6,000 tons and above were launched. Of these, 10 were over 10,000 tons each. At the end of December there were under construction, including a number of vessels already launched but not completed, 69 vessels of between 6,000 and 10,000 tons; 25 of between 10,000 and 15,000 tons; 10 of between 15,000 and 20,000 tons; 2 of between 20,000 and 40,000 tons; and 2 of over 40,000 tons each. Although the activity which has characterised the shipbuilding industry in the United Kingdom throughout the year 1912 has never been equalled before, the amount of tonnage actually launched during the twelve months for various reasons fell below the total output of 1911 by some 65,000 tons. Foreign shipyards, however, achieved a record output during 1912, having launched no less than 317,000 tons of merchant vessels in excess of the tonnage put into the water during 1911. The highest foreign individual increases for the year are: United States 66 per cent., Germany 50 per cent., and Italy 45 per cent. Of the tonnage launched in the world during 1912, the United Kingdom has acquired 15·8 per cent, while 60 per cent. was launched in the United Kingdom.

The Training of Apprentices.—The Edinburgh Merchant Company has just issued an important report on the training of apprentices, prepared by a joint committee appointed by a conference of representatives of educational bodies and of commercial associations in Edinburgh, held in June, 1911. The committee formulated the following preliminary proposals: (1) That each trade should appoint an apprentice training committee for the Edinburgh district to supervise the proper training of apprentices; that this committee should contain representatives of the employers, representatives of the workmen, and representatives of the educational authorities at present engaged in technical instruction; that there should be prepared a list of firms who were willing to work in conjunction with this apprentice training committee; and that the committee should draw up a list of all the apprentices employed by these firms, with full information as to the number of years of apprenticeship, the classes, if any, being attended, and the certificates gained. (2) That this apprentice training committee should consider as to framing systematic scheme of education for the apprentices, and what course should be followed to induce them to pass through such a course of training. (3) That the apprentice training committee should also consider what steps if any should be taken with a view to developing further the method of education at present in vogue. Apprentice training committees, composed of an equal number of employers and workmen, were appointed, and a general agreement was come to on the following lines: (1) That the apprentice training committee, as at present constituted, should for the ensuing year control apprentices in all matters relating to their training; (2) that the expenses of management, apart from any voluntary grants which may be received, should be borne mutually by the masters' and workmen's associations; (3) that lists of employers and apprentices should be got from the masters' association; (4) that all apprentices should be registered by cards in a form proposed by Principal Laurie; and (5) that a certificate by the apprentice training committee should be granted to each apprentice on the completion of his term of service. The committee further report that it would be difficult to revive the system of indenture in trades where it has been wholly or partially abandoned, and they do not think the time is ripe for embodying any proposed reform in a legislative measure.

The World's Coal Production.—The total known coal production of the world in 1911, according to a return just issued by the Board of Trade, was about 1,050 million tons, of which the United Kingdom produced more than one fourth and the United States more than two fifths. This excludes brown coal, or lignite. The outputs of the five principal coal producing countries were: United States, 443,025,000 tons; United Kingdom, 271,899,000 tons; Germany, 158,164,000 tons; France, 38,023,000 tons; Belgium, 22,683,000 tons. In the United Kingdom, Germany and France the production exceeded that of any previous year, but in Belgium it was less than in any of the preceding five years, and in the United States it fell short of the 1910 total by 1¼ million tons. The aggregate output of these five countries—nearly 934 million tons—showed an increase of 11 million tons on 1910. Russia is the only other country producing 20 million tons yearly. Though the United States production in 1911 exceeded that of the United Kingdom by nearly 60 per cent., this country's output per head is still the greatest, being 6 tons, compared with under 5 tons in the United States, 3 tons in Belgium, and 2½ in Germany, and less than one ton in France. The average value of the coal produced at the pit's mouth during 1911 is given as: United Kingdom 8s. 1¾d., Germany 9s. 9¾d., Belgium 12s., United States 5s. 10¾d. This represents a fall of ½d. in this country and 2½d. in Germany; and a rise of ½d. in the States and 1¾d. in Belgium. A far larger number of persons are engaged in the coal mining industry in the United Kingdom than in any other country, the leading figures for 1910 being United Kingdom 1,027,500, United States 725,000, Germany 621,100. We only produced, therefore, 257 tons per person employed, compared with the United States output of 618 tons. Both in this country and Germany the amount tends to decrease. As an exporting country the United Kingdom still stands easily at the head of the list with a net export of 87,040,000 tons, the nearest rivals being Germany with 24,727,000 tons and the United States with 17,603,000. The United States consumed 4·54 tons per head as compared with 4·08 in this country. Belgium used 3·21 tons per head, and Germany and France only 2·03 and 1·44 tons respectively, owing largely to the use of other fuels. The petroleum production of the United States in 1911 was 7,713 million gallons, an increase of 381 million gallons over 1910; while that of Russia decreased by 108 million gallons.

Association of Electrical Station Engineers.—The formation of an association devoted to the interests of electrical station engineers was decided on at a meeting held on the 16th inst., at which 21 representatives of electrical stations attended. It was announced that close on 1,000 engineers had promised to join the new association. A general meeting has been arranged for February 6th. The following resolutions were passed: (1) That the Association be called "Association of Electrical Station Engineers." (2) That the objects of the Association be: To raise the efficiency and general status of members of the Association. To provide means for social intercourse among its members, for their improvement, advancement, and recreation. To form an information bureau for the general assistance of members and employers. (3) That the essential qualification for membership shall be that the prospective member must be qualified for, and hold a responsible position in, an electrical undertaking for power, lighting, or traction. Mr. W. J. Ehlen was elected hon. secretary.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Aerial machines. Nosworthy & Prescott. 22025.
Universal couplings. Hardy. 21181.
Conveyer chains. Goulden & Reeson. 26308.
Apparatus for the continuous distillation and purification of crude petroleum coal tar. Barbet. 27005.
Charging machines for gas retorts. Aldridge. 27165.
Internal combustion engines. Cleaver 27279.

1912.

Valves for internal combustion engines and driving means therefor. Russell. 172.
Propellers for navigable vessels, airships, &c. Parsons. 200.
Furnace draught indicator. Von Lossau. 244
Engine or means for generating power. Wall. 297.
Furnaces for steam generators. Anderson, Meikle, & Fulton. 304.
Change speed gear. Buddicom. 324.
Hydraulic apparatus. Hele Shaw, Martineau, & Beacham. 336.
Apparatus for preheating the fuel of oil fired steam generators. Yarrow. 527.
Furnaces for melting metals. Davis. 550.
Internal-combustion engines. McGuire. 585.
Fire-bars for furnaces. Beeching & Spetch. 619.
Steam boilers. Hudson. 655.
Fuel and water injection devices for internal combustion engines. Rundlof. 689.
Superheaters. Wincqz. 698.
Valves of internal-combustion engines. Ford. 823.
Valve gear for internal combustion engines. Wolseley Tool and Motor Car Company, and Remington. 831.
Apparatus for turning, shaping, and screw cutting. Land. 888.
Tachometer or speed indicator. Brown. 1351.
Manufacture of manganese steel. Potter. 1479.
Worm gearing. Robinson. 2067.
Speed-indicating instruments. Cash. 2078.
Acetylene gas generators. Forsyth. 2590.
Crucible furnaces. Ionides. 2839
Combined steam and internal combustion engines. Beech. 2889.
Starting systems for internal combustion engines. Bell. 2960.
Vices. Bottomley & Lindley. 3155.
Control and propulsion of flying machines. Roe. 3588.
Expanding boring head and screwing head. Bradley. 3716.
Treatment of metals. British Thomson Houston Company. 3752.
Method for the microscopic examination of test pieces and for obtaining micro photographs of same while under strain. Winder. 3891.
Furnaces. Sillery. 4162.
Rotary engines. Fletcher. 4437.
Driving and reversing gear. Bateman & Bateman. 4461.
Method of bending pipes. Schitzkowsky. 5238.
Automatic block system for preventing collision between trains. Icard. 5352.
Driving mechanism for speedometers. Beckmann. 6556.
Steam superheaters. Bolton. 6765.
Steam superheaters for locomotive boilers. Robinson. 6774.
Manufacture and production of artificial fuel. London Industrial Contract and Finance Syndicate, Ltd., and Eaton. 6981.
Furnace fronts. Hume, and James Howden & Co. 7437.
Internal-combustion turbines. Kasley. 7960.
Automatic coupling devices for railway vehicles. Prokin and Misskewicz. 8156.
Stop-mechanism of turret lathe slides. Herbert & Vernon. 8393.
Annealing ovens. Falter. 9024.
Extraction of copper and nickel from low-grade ores and products. Borchers & Pedersen. 9146
Steam power plants Warwick Machinery Company (1908). 9524.
Rotary internal-combustion engines. Crayssac. 9716.
Steam superheaters. Stenning. 9727.
Carburetter for internal combustion engines. Smith. 10292.
Ships. Muir. 10468.
Coke ovens. Moss. 10819.
Valves. Froehlich. 12043.
Feed check valves for boilers. Buckland. 12207.
Motors. Orth. 12579.
Gauges for verifying the dimensions of screws and screw threads. Dubail. 13710.
Aeroplane. Dandrieux. 13855.
Apparatus for treating or softening water. Wilson. 13912.
Water-tube steam generators. Stirling Boiler Company. 13965.
Rotary valves for internal-combustion engines. Bright. 14073.
Water-tube boilers. Couperie & Bernard. 14743.
Internal combustion engines. Kind. 15132.
Liquid transmission of power apparatus. Karminski, Peters, and Bloch. 15136.
Recording indicator for steam engines. Graham. 16066.
Reversing carriages in grinding machines. General Composing Company Ges. 17063.
Device for regulating the extent of the feed movement in surface-grinding machines General Composing Company, Ges. 17395.
Chucks for percussive drills. Drinnan. 17477.
Process of refining aluminium. Leggett. 17594.
Turret lathes. Atkins & Cohen. 17994.
Shaft or axle bearings. Hani. 18581.
Three way plug valve. Blake. 18593.
Roller bearings. Newmann. 20618.
Railway rail joints. Weekes. 21636.
Automatic closure device for lubricators. Bled 22517.
Steam stop valves. Greatorex. 22799.
Floating cranes. Imray. 23761.
Automatic couplings for railway vehicles. Hinderegger & Klee 23957.
Means for consuming smoke in boiler furnaces. Imray. 24130.
Water engine. Spicker. 26348.
Cages for use in ball bearings. Bruhl. 26447.
Multiple spindle screw machine. Spencer. 26977.
Cylinder for superheated steam. Schmidt. 28765.

ELECTRICAL, 1911.

Electric Printing Telegraphs. Johnson, Varley, Michaelis, Power, & Johnson Secret Wireless Telegraph and Telephone Testing Syndicate. 22079.

1912.

Telephone systems. Derriman. 687.
Electric lamp holders. Day. 750.
Electrical apparatus for transmitting and receiving signals. Dawson & Buckham. 777.
Apparatus for the electrolytic manufacture of alloys of light metals with heavier metals. Ashcroft. 1001 and 1003.
Circuit interrupters for telephone transmitters. Logan. 1168.
Operation of direct-current motors. Peck & Eckmann. 1365.
Electric metallurgical furnaces. Stobie. 2081.
Telephones. Hammer. 4358.
Two-way electric switch. Markt. 4498.
Decreasing the injurious effects due to capacity in electric conductors. Becker. 6061.
Electric controllers. British Thomson-Houston Company, and Hastings. 7704.
Electric lighting apparatus. Dussaud. 8087.
Electric ignition device for internal-combustion engines. Bauer and Eckmeier. 9492.
Electro-magnetic separator for the wet separation of ores. Elektromagnetische Ges. 10619.
Regulation of electric installations. Earl. 11871.
Spark plugs. Forrester. 12809.
Electrical switch contact devices. Hosford. 13432.
Automatic electro-magnetic cut-outs. Wessel & Gysler. 14120.
Production of high-frequency oscillating currents Feeny. 14735.
Electric ignition apparatus. Rothschild. 14738.
Methods for compensating for the fluctuations in the load of electric motors. Siemens-Schuckertwerke Ges. 15469.
Magneto-electric machines. Hinksman. 15704.
Overhead contact conductors of electric railways. Bergmann Elektricitats-Werke Akt.-Ges. 15930.
Electric transformer boilers. Bally. 16043.
Revolving electric furnace. Soc. Generale des Nitrures. 16406.
Rotary magnets. Blathy. 16538.
Device for automatically adjusting the time of ignition in internal-combustion engines. Robert Bosch (Firm of). 17029.
Portable electric hand lamps. Hunt. 17850.
Hand regulated electric arc lamps. Rigby. 19099.
Connection apparatus for electric circuit conductors. Murray. 19535.
Electric locomotives and motor boats. Maschinenfabrik Oerlikon. 19890.
Arrangements for obtaining sparkless commutation in rotary converters coupled to alternating current boosters. Siemens Schuckertwerke Ges. 23285.
Connectors for electric conductors. British Thomson Houston Company. 25775.
Differential arc lamp with inclined converging electrodes. Korting & Mathiesen, Akt.-Ges. 26318.
Solenoid coil for alternating current arc lamps. Korting and Mathieson Akt.-Ges. 27024.

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A Proposed New Power Unit: The Myriawatt.

AN attempt is being made in America to add another to the long list of electrical units with which engineers are familiar, and as the attempt has the official support of the American Institute of Electrical Engineers, and also of the American Society of Mechanical Engineers, it seems desirable that notice should be taken of it. The attempt had its origin in a proposal made in a communication by H. G. Stott and Haylett O'Neill to the Electrical Engineers to connect the steam output of the boiler with the electrical output of the generator. Stated briefly, it is an effort to revive our old and obsolete friend "boiler horse-power." The authors of the suggested unit "Myriawatt," which as its name implies is 10,000 watts, or 10 kw., base its claims upon the resemblance between the value of this unit in B.Th.U.'s per hour, viz., 34,150 and the value of a very artificial American unit for "boiler horse-power," viz., 30lbs. of steam raised from water at 100° Fah. to a pressure of 70lbs. per square inch, which is equivalent to 33,479 B.Th.U. per hour, and is roughly assumed to represent the evaporative duty of 10 sq. ft. of water tube boiler heating surface. Thermally speaking, one horse-power, 33,000 ft.-lbs. per min., is 2,547 B.Th.U. per hour, more or less, according to the value assigned to the mechanical equivalent. But there is obviously no relation whatever between this value and 33,479 B.Th.U.'s, and to assume that because this latter number approximates to 34,150 B.Th.U. per hour—the thermal equivalent of 10 kw. per hour—it will, therefore, simplify the relations between boiler output and generator output is absurd, quite as absurd, in fact, as earlier attempts to link steam boiler outputs with steam engine outputs proved, after boiler pressures had risen above the atmospheric level. There may have been some justification of the phrases "boiler horse-power," and the "nominal horse-power" in the days when pressures were at a con-

mon level and steam boilers were equipped with vacuum valves, but this disappeared entirely when pressures began to rise, and became utterly meaningless when engine speeds varied also within wide limits. The introduction of the term "Myriawatt" will not in any way simplify the relation between the steam boiler and the electrical generator to-day, and is not likely to find any favour in this country. Without a more general consensus of opinion as to its utility it is to be trusted no sanction will be given to its use by the International Electro-Technical Commission which has recently been sitting in Switzerland, and to whom the suggestion has been referred. The "Myriawatt" fulfils no purpose that could not well be fulfilled by the kilowatt, and there is nothing to prevent anyone rating their boilers by this unit if they so desire. In any case, the connection between the steam boiler and the generator can only be established by an intermediate prime mover, and all the engineer wants to know about the boilers in dealing with the calculation of power is how much steam they will produce at a given pressure in a given time. What amount of power or electricity is produced is another question depending on the efficiency of the prime mover and generator, and the relationship between them and boiler performance is not, in our humble opinion, simplified in any way by introducing into the calculation an electrical unit of the kind proposed.

Progress in Steel Manufacture.

To those who live in an age of rapid progress, familiarity and close contact often tend to destroy a proper sense of perspective and correct appreciation of the advances made. This is forcibly impressed upon us by a perusal of Professor Arnold's recent lecture before the Royal Institution. Many engineers can recall the interest excited when Mushet first introduced his self-hardening steel to tool makers some 40 years ago, and the feeling for a long time prevailed that the last word on cutting steel had been said. The display made by the Bethlehem Steel Company at the Paris Exhibition in 1900, with tools made by the Taylor-White process, which showed mild steel being cut at a speed which rendered the nose of the tool red-hot, came as a startling demonstration of undreamt possibilities, until subsequent enquiries showed that the chemical composition in their alleged patent embodied nothing that had not been included in the Mushet type of steel some 20 years previously, though the possibilities of these had lain dormant. The Paris demonstration undoubtedly gave a great impetus to Sheffield tool steel makers, and although the claims of the Taylor-White patent were subsequently pronounced to be invalid, no one can deny the important stimulus they gave to further discoveries. Experimental researches have carried forward the results they attained with astounding rapidity, until at the present day engineers are familiar with "high-speed" steel in which the thermal stability of the fortified hardenite is about 700° C. The awakened interest and research into the metallurgy of steel has been not less prolific of results in other directions, and it is pleasant to feel that in these enquiries the Sheffield University has led the way. The researches of Professor Arnold and Dr. A. McWilliam threw a flood of light on the chromium steels, and later researches respecting the influence of vanadium have revealed the existence in connection with this alloy of physical properties as remarkable as any previous ones, especially in regard to tenacity and elasticity. It was only so recently as January, 1909, that Professor Arnold predicted the coming of a new British steel having a cutting power four times as great as the best steel then on the market, and so rapidly has been the skilful application of vanadium by Sheffield steel makers that this prediction is already practically fulfilled.

ELECTRICITY IN MINES.

At a joint meeting of the Yorkshire branches of the National Association of Colliery Managers and the Association of Mining Electrical Engineers, held at Leeds on Saturday last, a lecture was delivered by Prof. D. Bowen, of the Mining Department, Sheffield University, entitled "An Account of Experiments on Safety Devices in connection with Electrical Machinery for Coal Mines." Prof. Bowen prefaced his remarks with a careful and critical review of the experiments of German and American investigators, which he summed up as being inconclusive and carried out without any real knowledge of what was required under practical conditions. The future of the economic working of coal mines was, in his opinion, unquestionably bound up in the application of electric power and machinery in mines. No one who had compared other systems of the transmission of power with transmission by electricity had any doubt as to the superiority of the latter. During the past few years a very considerable amount of anxiety had existed in the minds of mining engineers as to the dangers attending the use of electricity in mines, and this uneasiness was justified to a certain extent by the faulty designs placed upon the market.

In consequence of the scare created by the occurrence of certain disastrous explosions which might possibly have been caused by defective electrical apparatus, there had recently been introduced in this and other countries legislation of a restrictive character. In this country electrical machinery and apparatus were now placed on the same plane as naked lights, and they were considered as being more dangerous than ordinary so-called safety lamps. The problem was, he said, capable of a satisfactory solution, but it was essential to have the co-operation of colliery managers and mining engineers, and similar support was asked for on the part of all concerned in the electrical industry as applied to mining, and there were reasons for hoping that this support would soon be forthcoming.

The composition of explosive mixtures found in mines was dealt with by Prof. Bowen, and the latter portion of his paper described in detail the various types of safety devices on the market or suggested. These included the flange protection, wire gauze protection, perforated plates, plate protection, tube protection, and labyrinth protection. The results of the German, United States, and Prof. Bowen's own experiments demonstrated that plate protection—based on the same idea as that underlying flange protection—was so far the safest devised. The value of oil for its spark quenching properties in high-tension switches, transformers, &c., was also dealt with. The experiments described demonstrated the fallacy of the common supposition that increased capacity in a safety-casing gave greater pressure on explosion. The conclusion he arrived at finally was that no protective device was effective unless it prevented any flame or incandescent spark to pass through, and a point of importance that had been established was that the pressure was increased where fans were inserted in the motor-casings, as a result of the agitation of the explosive atmosphere inside.

Safety of Automatic Signalling.—A denial of the criticisms which have recently been levelled against the system of automatic signalling in use on the London Underground Railways is given by Sir Horatio Yorke, the Board of Trade Inspector, in a report published on the 23rd ult. concerning the enquiry recently held into the collision on the Great Northern, Piccadilly, and Brompton Railway on September 4th. He states that "As many sensational statements have been published in connection with this incident, I think it right to say that, in my opinion, there is no reason whatever for suggesting that automatic signalling has proved to be a failure. Of course, no machine has yet been, or ever will be, constructed which will never break down. If it had been, we should have attained the realisation of the chimera of perpetual motion. But I am sure that with proper attention and maintenance automatic signalling, combined with train stops, may be regarded at the present time as the safest system that can be adopted on the underground electric railways of London, and, in fact, as the only one whereby the dense traffic on those railways could be conducted."

LARGE BATTERIES FOR LIGHTING LOADS.

In the course of a paper entitled "The Use of a large Lighting Battery in connection with Central Station Supply," read by Mr. F. H. Whysall before the Manchester section of the Institution of Electrical Engineers, on January 28th last, the author referred to the results obtained during two years' working of the 12,000 ampere-hour battery installed in March, 1910, at the Manchester Corporation Electricity Works, Dickinson-street, which at that time was the largest battery ever constructed. The paper also showed to what extent the predictions regarding the use of the battery had been fulfilled and the relief obtained in the cost per unit supplied. The battery consisted of 210 cells, each cell containing 38 positive plates and 39 negative plates of the following dimensions:—Positive plates, 20¾in. wide by 29in. deep by 0·4in. thick; negative plates, 20¼in. wide by 29in. deep by 0·31in. thick. The positive plates were of the Planté formation, cast in one piece, but the negative plates were of the improved box type composed of half-grids securely riveted together, the spaces between them being filled with active material. Specially impregnated wooden separators were employed between adjacent plates, and a free space of 8in. was left at the bottom of the cell for the accumulation of deposit.

The chief duty of the battery was to take 3,000 kw. off the lighting peak. It was also regarded as a stand-by. But its chief duty was load-levelling; and it was therefore decided to have three hand-regulated reversible boosters, and to run them in parallel at times of maximum discharge. At other times one or two would be used as required. It might be noted, however, that such importance was attached to the question of overload in emergency that it was the universal custom on the continent to use regulating cells in all central-station batteries.

The improvement in load-factor on the units generated, observed monthly over two years, was approximately 7½ per cent., and the value obtained from the chart was 0·08d. on 30½ million units, representing a saving of £10,166. There were, therefore, two distinct annual savings on running charges due to the battery—(1) stand-by boiler fuel costs; and (2) difference between steam generation at 8 per cent. load-factor and fuel bare cost.

The author, in concluding his paper, said that batteries were installed, when central stations were first built, large enough to maintain the supply during the night, and at the week-ends, without the assistance of running plant. They were found a great convenience; but generators would be added as the demand on the station grew, and the battery would fall out of use, except for balancing purposes, until, through neglect and ill-usage, it would become of no value to the scheme. In no case would the battery be used except as a luxury, and it was generally expected to require no attention until it got into a very bad state. It was now being recognised that, provided the battery was installed to reduce generating plant, it was a sound commercial proposition when considered in connection with a large lighting load.

Too much had, he observed, been made in the past of the supposed inefficiency of batteries; as a matter of fact, 70 per cent. commercial efficiency could be maintained with care; and if this were not so, efficiency was the least important attribute of peak-load plant, and especially so in the case of a battery. Peak-load units were costly to generate, and allowance was made for this in fixing charges for lighting. Power or daylight units were much lower in price because the cost of generation was much less—so in effect the battery was charged at power costs, and discharged at lighting rates. If some of the large consumers on public supply mains only realised this, they would install batteries of their own, buy current at power rates, and cheapen their own lighting supplies by arranging with the supply authorities for a "restricted-hour" supply, *i.e.*, they would take no current from the mains at peak-load time. Batteries hitherto had usually only been installed by consumers for the sake of making supplies reliable and independent of accidents outside their own premises.

It did not matter how short a period of time during the day, or the year for that matter, a supply was demanded, there must be plant installed to meet it, and it had been found that for all duty of less than 8 per cent. daily load-factor, *i.e.*, of less than two hours' demand during the 24 hours of the day, the matter was in no doubt. It most certainly paid to make storage battery provision for this. Beyond this point advantages must be looked to other than direct saving in capital cost and running charges to justify the extension of the principle. It was often said, "What about the overload capacity of the steam plant; was not this sufficient to deal with the peak the battery was intended for?" On occasion, yes; but if reliability of supply was to be assured, the occasion must be that brought about by the failure of the battery, a possible but unlikely occasion if proper care was taken.

Booster regulating plant could go wrong, and batteries were protected normally by circuit breakers which might open through defect. It was generally possible, however, in the event of serious trouble to parallel the battery without the boosters in circuit; and under such circumstances the battery would prevent total failure of supply under the worst conditions. From other causes of failure a battery was practically free. It was very important that the battery should be of large enough capacity, not only for normal discharges, but for any short, heavy loads it might be called upon to give out. On the other hand, if the battery was larger than would be necessary to deal with load of the proportions indicated, the direct saving it was possible to show was correspondingly decreased.

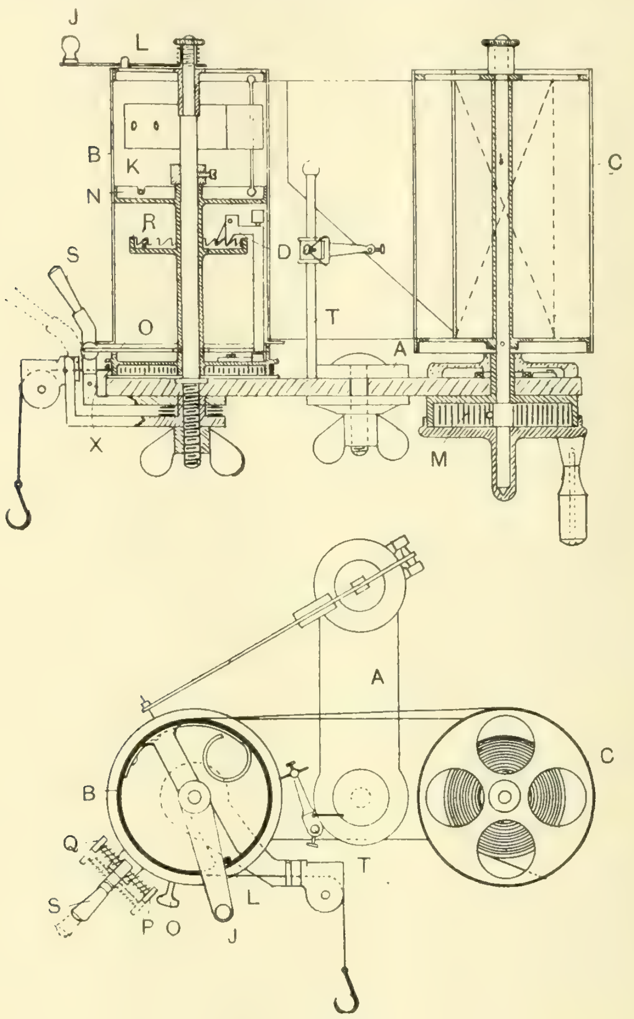
THE PROGRESS OF ELECTRICITY.

At a recent meeting of the Birmingham Electric Club, Mr H. Roberts delivered his presidential address, in which he dealt with the progress made in the science and use of electricity since the advent of the first arc lamp about 100 years ago. Induced currents were established in 1831, but it was 36 years after that time, he said, that the possibilities of the dynamo were realised. Following the invention of the Ediswan lamp in 1878 electricity was boomed, and many companies were formed to exploit it. A large number of people took shares in these companies, and hundreds lost their money. This led to the passing of the Electric Lighting Act in 1882, the object of which was to protect the public, but it also succeeded in crippling the industry, until it was repealed six years later. At this time electric light was more or less of a luxury, and currents were generated for lighting only. The total number of lamps connected in London even in 1893 was only 349,000, and only 50 towns in the United Kingdom had generating stations of their own. He then proceeded to trace the vicissitudes of the industry in its competition with gas lighting, and the growth of the use of electricity for power purposes, an epoch-making event being the opening of the London Electric Railway in 1890. From that time electric lighting had gone on until to-day every city and town of note, and even outlying villages, had their electric supply.

Coal Dust Explosions and their Prevention.—A paper on this subject was read by Dr. W. E. Garforth, at the University College, Nottingham, on Saturday last. He said the recent experiments at Altofts had led to the conclusion that if the principle be adopted of strewing stone dust wherever there was coal dust, an effective remedy for a coal dust explosion existed. It had been proved that stone dust could be applied in practice in such a manner as to be thoroughly effective, for, wherever coal dust could find its way, the fine stone dust could also be easily deposited, rendering the coal dust innocuous. Dr. Garforth emphasized the great importance of carrying out the principles of stone dusting in the most rigorous manner, and at the same time pointed out that much could be done towards preventing accumulations of coal dust by not allowing coal dust made on the surface to be carried down the downcast pits and by keeping tubs dust tight. If these measures were carried out he believed that the risks of explosion would be reduced to a minimum, and collieries would be put in a safer condition than at any previous period in the history of coal mining.

GRAHAM'S CONTINUOUS INDICATOR.

The accompanying illustrations show a design of indicator for steam or gas engines in which a continuous series of diagrams are produced on a long strip of paper, the invention of Mr. James Graham, Oak Street, Southport. There are several designs of indicators of the recording or continuous type already in use, but the design under notice differs from these in the fact that it is provided with a double-acting escapement for giving an instantaneous feed of the paper. This feed occurs in every case at the toe of the diagram, thus recording every successive stroke of the engine in an accu-



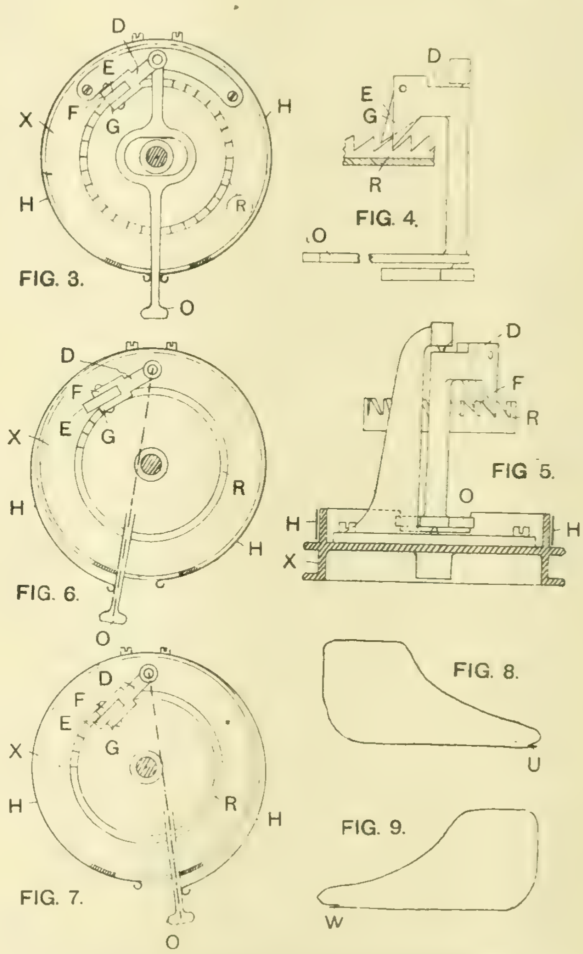
Figs. 1 and 2.—Graham's Continuous Indicator.

rately drawn enclosed diagram, which may be calculated for mean effective pressure in the usual way, also long records up to 120 lineal feet may be taken in ink or in pencil by this instrument. Figs. 1 and 2 show a general arrangement of the instrument, Figs. 3, 4, 5, 6, 7, show the escapement details, Figs. 8 and 9 show sample diagrams. The usual pendulum or other reducing gear is employed for communicating a reduced piston motion to the record drum. Use is also made of the steam part of an ordinary steam engine indicator. The ordinary record drum, however, is removed, and in its place is fixed the apparatus described below.

The arrangement consists of a base on which is mounted the record drum B and idle drum C, the whole being attached to the indicator arm A by a bolt, so that the record drum B occupies the correct position for the ink marker on the pencil lever. The record drum oscillates in the usual way, due to the reducing gear motion being connected up to the cord which works this drum. The idle drum contains the supply roll of paper inside the casing. The paper is wound by handle J on to the record drum. This handle also acts as a tell-tale, and is provided with a spring friction fulcrum, so that the handle remains at rest though the drum B is working; when pin L taps the handle at each oscillation it pushes it forward, thus showing when the paper is feeding. The paper tension is produced by winding up the coiled spring M by the crank handle situated below the idle drum. When the indicator cord is pulled forward by the reducing gear, the paper uncoils from the idle drum and coils on to the record drum. For the return stroke this process is reversed. After the diagram is drawn by the ink marker the record becomes wrapped round the outside of drum C due to the pulling action of the coiled spring M. The paper feed takes place instantaneously at the toe of the diagram due to the escapement lever O striking the adjustable spring buffer P for a front end diagram, and Q for a back end diagram. One tooth on the escapement wheel R escapes each time this striking action occurs.

An ordinary diagram can be taken by throwing back the lever S as shown by dotted lines; this removes the spring buffers P and Q from the path of the escapement lever O so that the striking action is omitted, consequently no feed takes place. In this case if the ink marker is kept on the paper, successive diagrams will be piled up on the top of each other. The pillar T carries a pencil arm having a spring action on the paper; the arm can be adjusted to any height so that a continuous atmospheric line is drawn on the record. Without interfering with recording, the idle drum may be wound up at intervals by turning the crank handle. On completion of an indication the cord is unhitched from the reducing gear, the paper released from drum B, unwound from the outside of the idle drum, severed, and removed from the instrument.

The cord drum X is actuated in the usual way. Inside



Figs. 3 to 9.—Graham's Continuous Indicator.

this cord drum a bracket is fixed which carries between centres the escape lever fulcrum. The lever O passes out through an opening (Fig. 3) in the side of the cord drum X, whilst the upper arm D engages the saw-teeth of wheel R, causing release and instantaneous feed of paper each time a tooth is released (see Figs. 4 and 5). The escapement lever O when at rest occupies a central position in the opening, Fig. 3, so that the central advance tooth E engages the saw-teeth of wheel R; it is retained in this position by the circular spring H. The ends of this spring act on each side of the lever O, so that to whichever side the lever is pushed by the action

of the buffers P and Q it always returns to the central position; only one end of the circular spring H can act at the one time.

The central advance tooth E in its normal position, with reference to its fixture, stands out, one tooth pitch in advance of the two fixed teeth F G, and is held in this position by means of a spring; the tooth may, however, be pressed back flush with F G (as it is after release) or it may be pulled forward as in winding on paper on the record drum, in which case it acts as a ratchet tooth, that is, it allows winding on of paper but opposes unwinding. In recording the escapement action is similar to a typewriter carriage escapement, excepting that in this indicator it is double-acting, the release occurring on the return stroke after the lever is pushed over to the one side or the other. Fig. 3 shows the escapement lever O in its central position, that is, the advance tooth E is pressed flush with the two fixed teeth F G, due to the pull of the paper pressing the wheel teeth R against the tooth E. When the escapement lever O is pressed over, as in Fig. 6, the advance tooth E escapes one tooth pitch forward and waits there, outside of wheel R, but no feed of paper occurs because fixed tooth G holds wheel R and prevents rotation. On the return stroke of the escapement lever the waiting tooth E slides back into the adjacent tooth space to that which it occupied on the outstroke, when G passes through clear of tooth ring, E is instantaneously pressed back flush with F G, as shown in Fig. 3. It is at this instant that the feed of the paper occurs. The action is exactly the same when the escapement lever O is pressed over, as in Fig. 7; the advance tooth E in that case projects inside the wheel rim R. The actual feed of paper occurs in each case on the return stroke of lever O, so that the toe of the diagram is completed when release occurs at the point U W, as shown in diagrams Figs. 8 and 9. The record drum B revolves freely on its central spindle, and is provided with a flange at the bottom edge to guard the paper from the escapement lever O. The disc N is slotted to form a driver for the pin K. A collar keeps the disc N in its place when drum B is withdrawn.

BOOK REVIEWS.

A Text Book of Mathematics and Mechanics. Specially arranged for Students qualifying for Science and Technical Examinations, by Chas. A. A. Capito, M.Sc., M.I.Mech.E.; with numerous diagrams and worked-out examples. London: Chas. Griffin & Co. 8in. by 5½in.; 398 pp. Price 12s. 6d. net.

Of text books on mathematics and mechanics there is no end, and amongst such a host it is difficult to single out particular ones for special praise. The differences mainly consist in the varying ideas as to the way in which the subject should be handled in dealing with students. In the volume before us the author, in his treatment, proceeds upon the assumption that the student possesses a good working knowledge of trigonometry and the calculus, and, unlike many British writers, who treat the straight line and the circle separately and subsequently deal with the parabola, ellipse, and hyperbola jointly as conic sections, he regards these, while treating them separately, as all belonging to one category, namely, sections of a cone. We agree with him that this is the natural and logical method. The book is accompanied with a number of well selected worked-out examples from questions set in the Institution of Civil Engineers' Examinations, and which should prove of assistance to students who are preparing for them.

* * *

The Gas, Petrol, and Oil Engine. Vol. II. By Dugald Clerk, D.Sc., F.R.S., M.Inst.C.E., and G. A. Burls, M.Inst.C.E. London: Longmans, Green, & Co. 9in. by 6¼in.; 838 pp. Price 25s. net.

This is the second part of a work, the first volume of which was published some three years ago, and which related mainly to an historical sketch and the general thermodynamics of internal-combustion engines. The one under notice deals mainly with practical problems of design, construction, and operation, and for this reason is probably of greater interest to makers and users. From a reference to the allocation of the two parts of the task involved in the writing and the compilation of the present volume, it would appear that the sections dealing with the development and prospects of internal-combustion motors, as well as the chapter dealing with gaseous fuels, are the work of Dr. Clerk, while the portions dealing with the more descriptive aspects of gas, petrol, and oil engines now in use are largely the work of Mr. Burls. Much of the volume is of course descriptive, but this is accompanied with comments and notes of performance, which, in view of the authors' experience, greatly enhances the value of the text. The work illustrates in an admirable manner how great has been the development of the internal combustion motor, notwithstanding the very serious constructional difficulties that have stood in its way, and which, though they have been largely overcome in respect to small units of power, still leave many problems only partially solved in the case of large units, so that while steam has in many fields been compelled to yield place to those operated with oil or gas, it still holds pre-eminence where large units are concerned, especially if the power requirements permit of the use of the turbine. Attempts to introduce gas into this particular type of motor have so far not been successful, and the temperature difficulties as they stand at present appear insurmountable. Notwithstanding the limitations in certain directions, however, it is impossible for anyone who can look back to the introduction of the first practical gas engine to avoid being struck with the enormous advances that have since been made. At that time engineers were justified, in view of existing knowledge, in regarding the problem of aerial flight as unattainable, and it is safe to say that it would still be awaiting practical solution had it not been for the advent of the motor-car and the development of the petrol engine, the ingenious developments and remarkable performances of which form one of the most interesting sections of the book.

BOOKS RECEIVED.

New Steam Tables with their Derivation and Application. By C. A. M. Smith, M.Sc., and A. G. Warren, B.Sc., with an Introduction by Sir Alfred Ewing, K.C.B., F.R.S. London: Constable & Co. 101 pp. Price 4s. net.

Examination Papers and Reports of Examining Committees on the General Examinations in Science and Technology. By the Board of Education in 1912. Printed by H.M. Stationery Office. London: Wyman & Sons, Ltd. Price 9d.

The Training of Professional Engineers. By Prof. John Goodman, Leeds University, London: Clowes & Son, Ltd. Price 7d.

New Brazilian Super-Dreadnought.—The super-Dreadnought "Rio de Janeiro," of 27,500 tons displacement, was recently launched at Elswick Shipyard. She is the largest vessel ever built by Sir W. G. Armstrong, Whitworth, and Co. at their Elswick yard. Her principal dimensions are: Displacement, 27,500 tons; length over all, 652ft.; beam, 90ft.; maximum draught, 26ft. She will carry 14 12in. guns of 50 calibres, 20 6in. guns of 50 calibres, 12 12-pounder guns, and 3 torpedo tubes. She is heavily protected with Krupp armour plate, the thickness of which is: Belt, 9in.; turrets, 12in.; and conning tower, 12in. She will have Parsons turbines of 45,000 i.h.p., and her guaranteed speed is 22 knots. The keel was laid originally in December, 1910, and she was to have been of 32,000 tons displacement, carrying 12 14in. guns, but this design was abandoned for that of the present vessel, the keel of which was laid in September, 1911.

An Interesting Modification of Hydrogen.—Sir J. J. Thomson, F.R.S., director of the Cavendish Laboratories at Cambridge, has discovered a new gas. It holds the same relationship to hydrogen that ozone does to oxygen, which means that its chemical formula is H 3. Although he has been working on the subject for over two months, the professor has only managed to obtain rather less than a cubic millimetre of the gas. He found this curious form of hydrogen hidden away in metals, especially iron, zinc, copper, and lead. They seem to dissolve it as a cup of tea dissolves sugar, but they are very chary about giving it up. It is not like ozone, for it is much less active than hydrogen. It will not explode mixed with air or oxygen. "I should have expected it to be a kind of superfluorine," he said. "But it had no action on the glass in which it was imprisoned."

THE CUTTING AND GENERATION OF GEAR TEETH BY MODERN GEAR-CUTTING MACHINERY.*

BY VINCENT GARTSIDE.

(*Concluded from page 110.*)

(*Concluded from page 110.*)

HELICAL AND SPIRAL GEARS.

UNDER this heading there are several different types of spiral and helical gears. (1) The simple spiral or single helical gear, cut with disc cutters or hobs, or planed. (2) The Lewellen double helical gear, cut with disc cutters. (3) The Wuest gear, cut with hobs. (4) The Chevron gear with multiple helical teeth, cut by end mills.

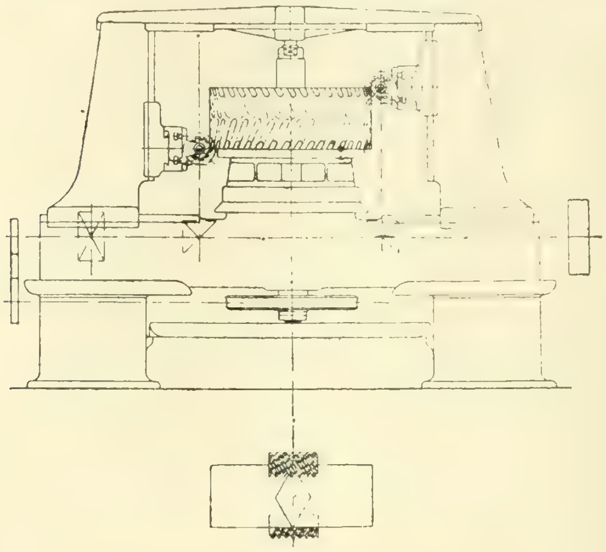


FIG. 32.

The principles employed in the production of simple helical gears apply to all other whether single, double, or multiple helical gears, as the multiple helical gears are equal to a number of single helical gears placed side by side but of different hand of spiral. Single helical gears can be cut with standard disc cutters, hobs, or flat planing tools (Sunderland type). In selecting a cutter when cutting with a disc cutter, the pitch is taken on a normal section, and in designing spiral gears this should be borne in mind and the centre distances fixed accordingly so that standard pitches of cutters can be used.

Spiral gears up to a few years ago were generally cut on universal milling machines, or machines with the same movements, the work being given a spiral movement as it passed the cutters, exactly the same as when cutting a multiple threaded worm, the dividing from one tooth to the next being done by hand. A large number of spiral gears are, however, hobbed, as a rack placed normal to the spiral will gear correctly, consequently they can be generated from the rack similarly to spur gears; they can also be cut on the "Sunderland" machine and generated from the rack tool in a similar manner. In every case, however, it is necessary to incline the cutter, tool, or hob to cut at right angles to the normal to the spiral.

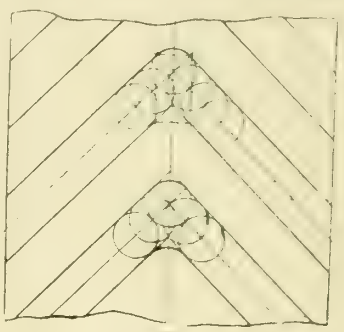


FIG. 33

In making double helical gears it has been customary until a few years ago to make them in halves, one half right-hand spiral and the other left-hand spiral and bolt together, but the general practice to-day is to make them solid, and the Wuest, Lewellen, and Chevron gears are all cut from the solid. In the Wuest and Lewellen gears the teeth are not continuous, there being a break in the centre of the wheel, but both makes of gears have the teeth staggered, viz., the teeth on one side of the gear are cut opposite to the spaces on the other side, thus ensuring smoother action.

The author understands that the Lewellen gears are cut with disc cutters, and each half is the same as a simple helical gear cut in a similar manner, but he has not any knowledge as to the particular type of machine used. With regard to the Wuest gears, however, a special process is employed and these gears are cut by means of hobs; but instead of inclining the hobs they remain parallel, and the angle of the spiral of the hob corresponds with the angle of the spiral of the wheel. Special machinery is also employed where the hobs are placed diametrically opposite to each other, one hob feeding up and cutting one side of the gear and the other feeding down and

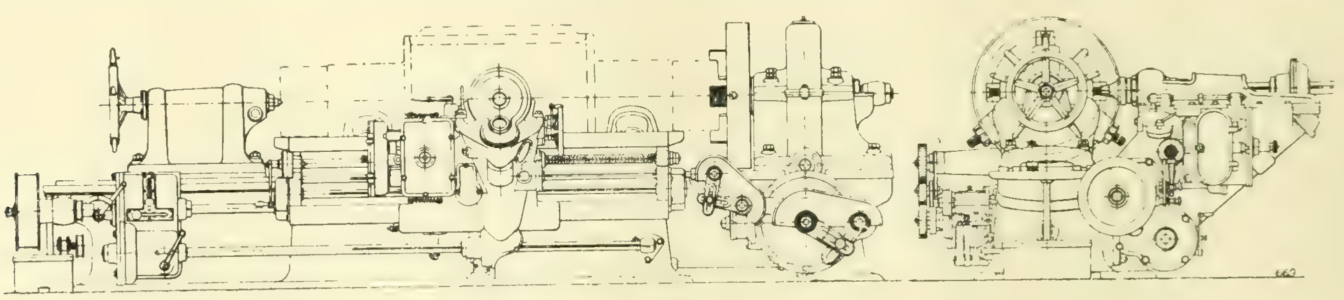


FIG. 34

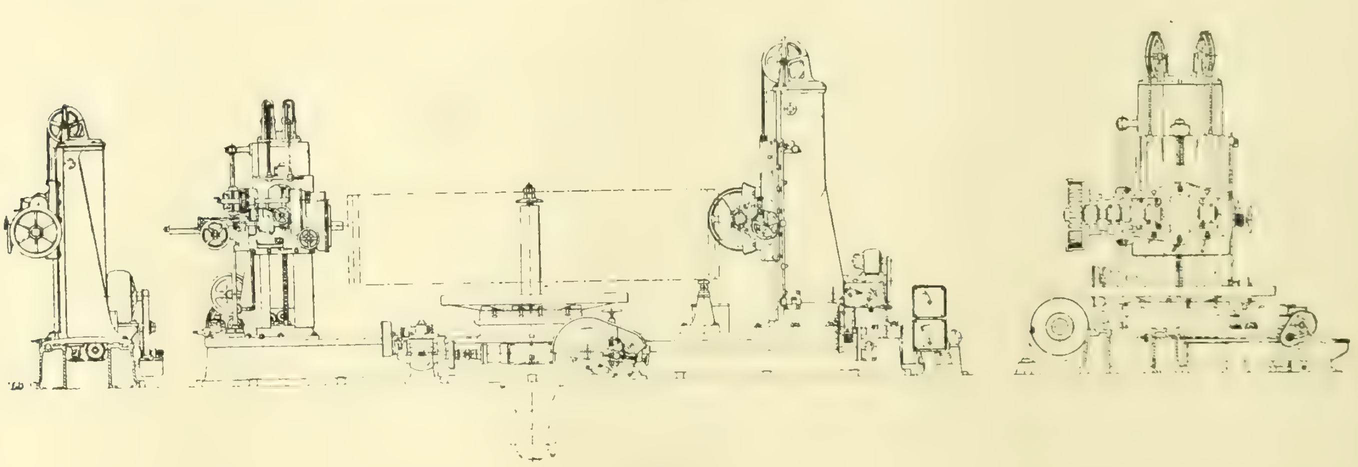


FIG. 35

* Paper read before the Manchester Association of Engineers, January 11th, 1913.

cutting the other side, each hob being of opposite hand spiral and cutting to the centre of the wheel. In order to cut as near to the centre as possible and with as little waste surface of tooth as possible, the hobs are made as small in diameter as convenient. The shape of the teeth are of the 20° involute standard, but of the stub tooth depth, and the depths are calculated from the normal pitch and not from the circular pitch as with the ordinary type of gears, but the axial pitch of the hob is the same as the circumferential pitch of the gear.

Involute Odontograph. (See Fig. 36.)

Standard Interchangeable Tooth. Centres on Base Line.

Teeth.	Divide by the Diametral Pitch. Face Radius.	Divide by the Diametral Pitch. Flank Radius.	Multiply by the Circular Pitch. Face Radius.	Multiply by the Circular Pitch. Flank Radius.
10	2·28	·69	·73	·22
11	2·40	·83	·76	·27
12	2·51	·96	·80	·31
13	2·62	1·09	·83	·34
14	2·72	1·22	·87	·39
15	2·82	1·34	·90	·43
16	2·92	1·46	·93	·47
17	3·02	1·58	·96	·50
18	3·12	1·69	·99	·54
19	3·22	1·79	1·03	·57
20	3·32	1·89	1·06	·60
21	3·41	1·98	1·09	·63
22	3·49	2·06	1·11	·66
23	3·57	2·15	1·13	·69
24	3·64	2·24	1·16	·71
25	3·71	2·33	1·18	·74
26	3·78	2·42	1·20	·77
27	3·85	2·50	1·23	·80
28	3·92	2·59	1·25	·82
29	3·99	2·67	1·27	·85
30	4·06	2·76	1·29	·88
31	4·13	2·85	1·31	·91
32	4·20	2·93	1·34	·93
33	4·27	3·01	1·36	·96
34	4·33	3·09	1·38	·99
35	4·39	3·16	1·39	1·01
36	4·45	3·23	1·41	1·03
37–40	4·20		1·34	
41–45	4·63		1·48	
46–51	5·06		1·61	
52–60	5·74		1·83	
61–70	6·52		2·07	
71–90	7·72		2·46	
91–120	9·78		3·11	
121–180	13·38		4·26	
181–360	21·62		6·88	
Rack.	Radius of Points 2·10 Diametral Pitch.		Radius of Points ·67 × Circular Pitch.	

Fig. 32 shows diagrammatically the arrangement of the machine for cutting this type of gear. The blank is driven round in correct ratio to the hob to suit the number of teeth in the gear and an extra added on motion is given to the wheel to give the necessary spiral angle which is 23°; the action of the machine is continuous as in all hobbing machines. By

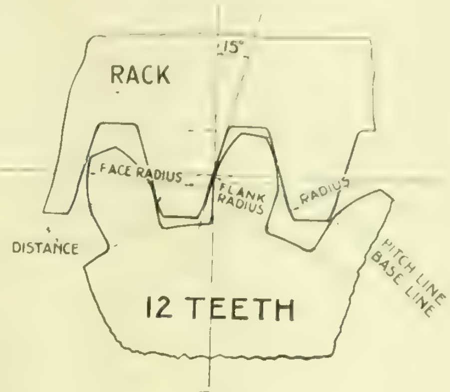


Fig. 36.

adopting the stub tooth and 20° pressure angle very small numbers of teeth can be cut without undercutting, consequently very high ratios are possible with this type of gear, in fact as low as four and five teeth can be cut in the pinions.

A method of cutting double and multiple helical gears which has come to the front very much lately is the cutting

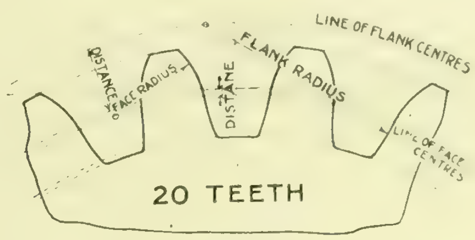


Fig. 37.

by end mills. Gears from 8 mod. to 100 mod. pitch are now cut by this method. The cutters have a profile the same as the normal section of the tooth spaces, and these cutters are generally made to gauges to suit the different pitches and shapes to be cut.

In the process of cutting the cutter is sunk into the wheel at one side and then is given a feed parallel to the axis of the wheel, at the same time a twisting motion is given to the wheel which gives the necessary spiral. When the centre of the wheel is reached, however, this spiral motion of the work is reversed so that the other half of the wheel is cut of an opposite angle of spiral, which gives the herringbone type of

Three-point Odontograph. (See Fig. 37.)

Standard Cycloidal Teeth. Interchangeable Series. From a Pinion of 10 Teeth to a Rack.

Number of Teeth in the Gear. Exact.	Intervals.	For One Diametral Pitch. For any other Pitch divide by that Pitch. Faces. Radius.	Faces. Distance.	Flanks. Radius	Flanks. Distance.	For 1in. Circular Pitch. For any other Pitch multiply by that Pitch. Faces. Radius.	Faces. Distance.	Flanks. Radius.	Flanks. Distance.
10	10	1·99	·02	8·00	4·00	·62	·01	2·55	1·27
11	11	2·00	·04	– 12·05	6·50	·63	·01	3·34	2·07
12	12	2·01	·06	∞	∞	·64	·02	∞	∞
13½	13–14	2·04	·07	15·10	9·43	·65	·02	4·80	3·00
15½	15–16	2·10	·09	7·86	3·46	·67	·03	2·50	1·10
17½	17–18	2·14	·11	6·13	2·20	·68	·04	1·95	·70
20	19–21	2·20	·13	5·12	1·57	·70	·04	1·63	·50
23	22–24	2·26	·15	4·50	1·13	·72	·05	1·43	·36
27	25–29	2·33	·16	4·10	·96	·74	·05	1·30	·29
33	30–36	2·40	·19	3·80	·72	·76	·06	1·20	·23
42	37–48	2·48	·22	3·52	·63	·79	·07	1·12	·20
58	49–75	2·60	·25	3·33	·54	·83	·08	1·06	·17
97	73–144	2·83	·28	3·14	·44	·90	·09	1·00	·14
290	145–300	2·92	·31	3·00	·38	·93	·10	·95	·12
∞	Rack	2·96	·34	2·96	·34	·94	·11	·94	·11

gear. In some cases this twisting action is changed three or four times in the passage of the cutter across the face of the gear, giving a zig-zag form of tooth. This type of gear can only be produced by this method.

Owing to the style of cutter used, roughing and finishing cuts are taken which give very satisfactory results. Before the gears are removed from the machine it is necessary to remove part of the central portion of the tooth, as shown in Fig. 33, as the point of the tooth would interfere with the curve in its mating gear owing to the cutter cutting across the axial section the same space as the normal section. In some cases the teeth at this point are rounded off, in others they are cut square across, and this is performed on the same machine.

Special machines for wheels and pinions of this type are made by Lorentz, Germany. Fig. 34 shows the pinion machine diagrammatically, and Fig. 35 shows a large machine which has a cutter head on one side for cutting the Chevron gears, and a head on the other side for cutting spur and spiral gears with hobs.

THE RESISTANCE OF ELECTROLYTES.

At a meeting of the Physical Society of London, a paper entitled "The Resistance of Electrolytes," by Messrs. S. W. J. Smith and H. Moss, was read by the former. Some experiments upon this question were exhibited before the Society in 1911. In these a modification of Wien's method was used—the optical telephone being replaced by a vibration galvanometer—and the conclusion was drawn from them that the resistance of an electrolyte varied to an easily perceptible degree with the frequency of the alternating currents to which it was subjected. The authors pointed out that the terminal difference of potential and the current in a branch of a network containing capacity and self-induction might be in the same phase although their ratio did not give the resistance of that branch. This would happen (whether the branch contained an electrolyte or not) if there was leakage through the condensers, causing the P.D.'s between their plates to be out of quadrature with the current. The apparent resistance of the branch would then be a function of the frequency of the alternating currents circulating in the bridge, and Wien's method would give this apparent resistance only. It was, therefore, unsound to use the method to test whether the resistivity of an electrolyte depended upon the frequency of the currents to which it was subjected, unless it was shown that the effects of leakage through the electrolyte condensers could be neglected or allowed for.

A particular case was indicated by the authors, in which the leakage could be made large or small at will. The results for this case had been interpreted by Krüger, without assuming any variation of resistance with frequency in a manner which seemed satisfactory to them In order, however, to remove or justify any doubt upon the question they had performed test experiments by a simple and direct method which was described. It depended upon simultaneous measurement of the voltage between the ends of a tube containing the electrolyte and of the current passing through it. The former was measured by means of an Ayrton-Mather electrostatic voltmeter connected to auxiliary electrodes and the latter by means of a Duddell thermo-galvanometer. In the cases examined it was found that the resistivity of the electrolyte was constant within 0·05 per cent., whether steady currents or currents of any frequency up to 2,300 alternations per second were used. Until the instruments were calibrated by means of a metallic resistance there appeared to be a small difference of about 1 part in 600 between the resistance as measured by continuous currents and the values obtained with alternating currents. Some supplementary experiments were made with the object of elucidating the peculiar behaviour of the instruments which this calibration disclosed. On account of the smallness of the effect its cause could not be completely ascertained; but the fact that the apparent contact P.D. within the voltmeter was a function of the applied voltage, decreasing as the latter was raised, would cause an effect of the same sign as that observed. Unallowed-for leakage, greater with steady than with alternating currents, might also provide a partial explanation of the results.

SUPPLYING AND VAPORISING FUEL FOR OIL ENGINES.

Several improvements in connection with oil engines have recently been patented by Messrs. Tangyes, Ltd., of Cornwall Works, Soho, Birmingham, in conjunction with Mr. James Robson, and comprise a vaporiser in combination with means for heating the liquid fuel, or the air, or both, on their way to the vaporiser, and with means for supplying the proper amount of liquid fuel in accordance with the load on the engine, and for the admission and regulation of the water injection to the engine cylinder, and with means whereby the engine can be worked either with a light liquid fuel, such as benzoline, or with kerosene, or fresh crude naphtha, or with gas direct from the oil wells, as the circumstances and conditions of working may demand. These are shown in the accompanying cuts, of which Figs. 1 and 2 are elevations at right angles to each other, showing the general arrangement of the apparatus attached to an engine. Fig. 3 is a plan, and Fig. 4 is a vertical section of the vaporiser, drawn to an enlarged scale. Fig. 5 is an elevation drawn to an enlarged scale of the combined benzoline and water injection valve and the gas valve.

The vaporiser consists of a casing A covered with non-conducting material and surrounding the exhaust pipe B through which the hot exhaust gases pass from the engine cylinder, the part of the exhaust pipe which is surrounded by the casing A being increased in diameter and having internal ribs to absorb as much as possible of the heat of the exhaust gases. At or near the top of the vaporiser is the inlet C for the liquid fuel, this fuel being led into a trough D fixed round the exhaust pipe B and having in its edge V-shaped notches to distribute the liquid fuel evenly over the surface of the exhaust pipe B. At the bottom of the casing A is an overflow pipe to allow any of the liquid fuel which has not been vaporised to flow away to any suitable reservoir where it can be collected, and in the case of refined liquid fuels, such as kerosene, used over again, or in the case of fresh crude naphtha being used, the residue overflowing and which is too thick to be used over again, can be refined in the usual manner. Near the bottom of the vaporiser is another opening E for admitting air which, in its passage through the vaporiser, comes into contact and mixes with the vaporised liquid fuel therein by passing through perforated or reticulated plates F, thus bringing about a very thorough mixing of the air and vapours before the mixture passes by the outlet G and through the cock Y to the engine cylinder. The air passed in at E is first heated by passing it in at H between the exhaust pipe and a surrounding tube and thence to the inlet E by means of a pipe J in which is a regulating cock. This pre-heating of the air is done in order to reduce the tendency to cool the inside of the vaporiser which would be the case if cold air were admitted. In addition to pre-heating the air, arrangements are also made for heating the liquid fuel before it enters the vaporiser. The liquid fuel on its way from the pump K first passes into a sight feed receiver L and thence to the inlet C through a pipe M, which encircles an extension of the exhaust pipe and is surrounded by a heat-protecting shield. The object of pre-heating the liquid fuel is to assist in its more complete gasification in the vaporiser.

The liquid fuel is supplied to the vaporiser in the proper quantity by means of the pump K, which is actuated as follows: An extension of the spindle of the gas valve N projects through a guide and engages with one end of the operating lever O, the other end of which engages with and operates the plunger of the pump, which is pressed upwards by a spring as shown. The fulcrum pin Q of the lever O is so arranged on a piece working on a screw R that it can be moved on the screw, that while one arm of the lever O is shortened, the other arm thereof is lengthened. From this it will be seen that while the stroke or lift of the gas valve N is constant, the stroke of the pump plunger P can be varied so as to regulate the amount of liquid fuel pumped at each stroke into the vaporiser, as may be required by the particular kind and quality of the liquid fuel used. When it is desired to put the pump K out of action, it is only necessary to slide the lever O sideways along an extension of the fulcrum pin Q (see Fig. 3) and retain it there. The engine illustrated is supposed to be governed on what is generally known as the "hit and miss" principle, so that the gas valve N is opened a greater or lesser number of

times in accordance with the load on the engine, and therefore, at each lift of the gas valve N, the pump plunger P will force a charge of liquid fuel into the vaporiser where it will be gasified in readiness for the next charge taken into the engine cylinder. When no lift of the gas valve N takes place, the pump plunger P will not be actuated and no liquid fuel will then be passed into the vaporiser. It will thus be seen that charges of liquid fuel are pumped into the vaporiser only in accordance with the load on the engine, and that the amount pumped in at each stroke of the pump can be adjusted by altering the position of the fulcrum pin Q to suit the conditions and the quality of the fuel used.

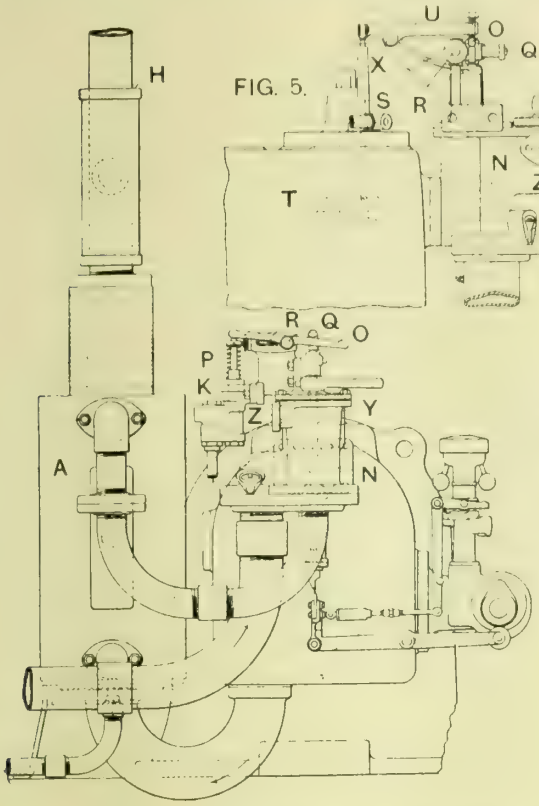


Fig. 1.

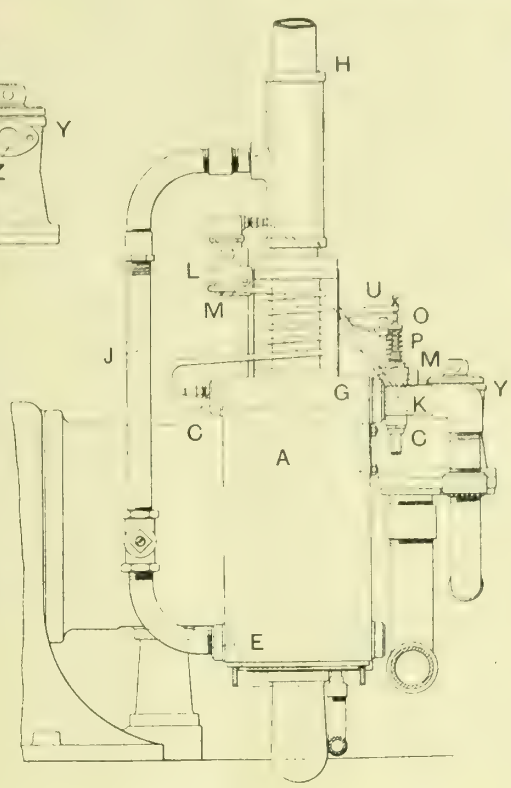


Fig. 2.

Arrangement for Supplying and Vaporising Fuel for Oil Engines.

Before the engine can be run with the vaporiser it is, of course, necessary to first heat the vaporiser. This is done by first running the engine with some other suitable liquid fuel, such as benzoline, or even oil-well gas when available. To enable this to be done, a combined benzoline and water injection valve S is fitted to the main air inlet valve box T (see Figs. 3 and 5). The valve S is operated by means of a lever U, one arm of which rests upon the top of the spindle of the valve S, while the other arm rests upon, and is operated by, the extension of the spindle of the gas valve N. When the engine is using benzoline as fuel, it will be understood that no gas or other fuel is passing through the gas valve N, the valve during this operation simply being used as a means for operating the valve S, at each opening of which valve benzoline is admitted which is sprayed and mixes with the entering air in its passage through the air-admission valve box T into the engine cylinder, where it is compressed and ignited, which may be done in the usual manner.

By means of a combined benzoline and water injection cock V, the correct quantity of fuel admitted to the engine cylinder can be regulated. The cock V is also arranged so that only either benzoline can be admitted to the engine cylinder, or, when gas from the vaporiser or other source is being used, water-injection can be admitted to the cylinder by setting the handle W to the proper position indicated by a dial plate for that purpose. The valve S is operated in either case from the gas valve N through the lever U, and then only in accordance with the load on the engine. When necessary, the valve S can be put out of operation by sliding the lever U along the fulcrum pin X and retaining it there.

Arrangements are also made whereby the engine can be run alone on the gas from the oil wells. When this is desired, the fuel pump K and the combined benzoline and water-injection valve S are put out of operation by moving their respective operating levers O and U out of gear as already explained. The plug of the gas cock Y is turned by its handle so as to shut off communication with the vaporiser and, at the same time, open communication with the opening Z to which is connected the pipe conveying the gas from the oil well or other source.

The main air supply to the engine cylinder is adjusted by means of a regulator in the air passage, in accordance with the kind of liquid fuel used.

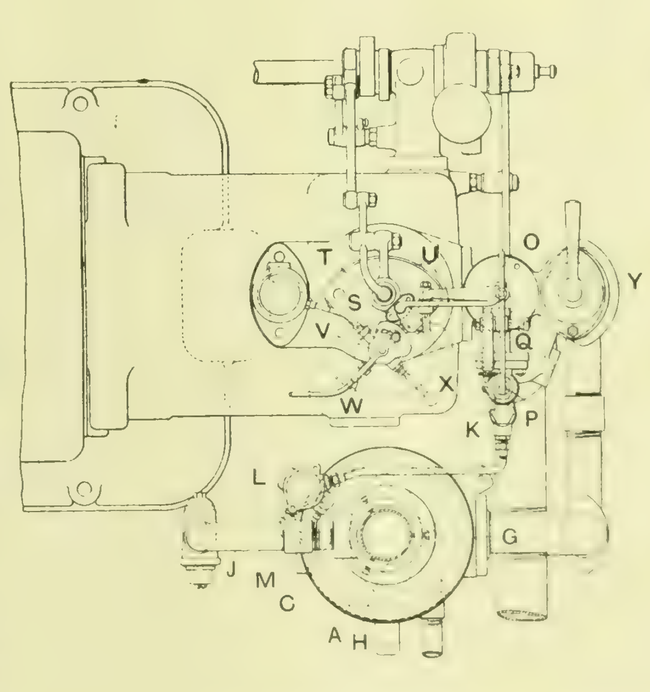


Fig. 3.

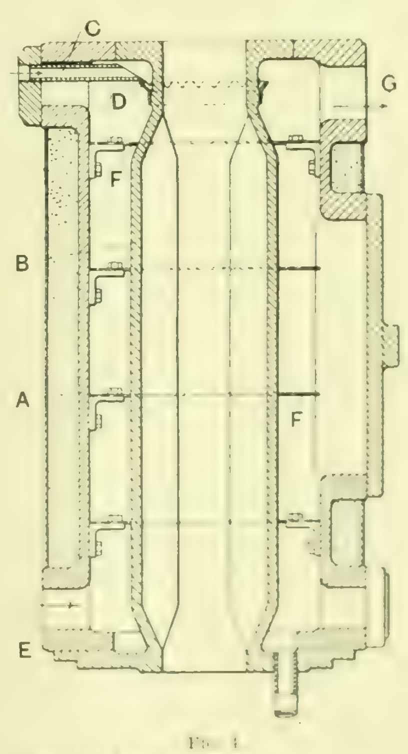


Fig. 4.

Arrangement for Supplying and Vaporising Fuel for Oil Engines.

Fatal Crane Accident. – An engineer in the employment of Messrs. Grant, Ritchie, & Co. was killed on the 20th ult. as the result of a crane accident. While the crane was raising a heavy load a link of the chain snapped, and the deceased was struck by the falling mass and sustained a fracture of the skull.

JOHANSSON COMBINATION STANDARD GAUGES.

THE whole tendency of engineering development during the last quarter of a century has been towards specialisation of industries with the object of cheapening cost by making large quantities of each separate article and manufacturing them accurately, so as to secure interchangeability. This end has led to a concentration on methods of measurement which has greatly stimulated the demand for gauges, possessing a degree of precision scarcely dreamed of a generation

FIG. 1.

ago. Absolute accuracy, as every engineer knows, is impossible, and since this axiom of construction has to be accepted in connection with the making of any interchangeable article, the only alternative is to so make it that any error in size shall lie between definite limits, and hence "limit gauges" have become a necessary equipment of every shop where accuracy and at the same time interchangeability are essential. The making of such gauges obviously demands extreme care, and the number of firms who have succeeded in satisfying trade requirements are few. Many adjustable measuring tools constructed for the purpose give a high degree of accuracy, but their use is connected with a series of difficulties which make them unpractical for easy processes of manufacture. The setting for each measurement means loss of time, the reading is difficult, and does not exclude errors, and lastly, we have the personal equation, the "Feel," which directly influences the result and makes it hardly possible for two men to measure alike. This is not only detrimental to the interchangeability of parts, but often gives rise to discussion and disputes.

These drawbacks to adjustable tools are nowadays generally acknowledged, and their efficient use is limited to occasional measurements. For regular work in the shop a simple tool, independent of the workmen's skill, is necessary, and for this purpose fixed gauges are generally used, one gauge being made for each piece of work, and size, and in this way the measurements are greatly simplified, and at the same time great accuracy is secured.

Still more reliable and more simple measurements can be made if each piece of work is measured with two sizes, viz., one smaller and one larger than the actual size required, of which the former represents the minimum size that the piece can be made to, and the latter, the maximum that the finished article can have without violating the condition of interchangeability or the function of the parts. Absolute accuracy can never be obtained, and is not necessary for practical work, because all parts allow certain variations from their exact size and still remain interchangeable. The variations must, however, be carefully calculated according to the special use of the different parts, and must be rigorously controlled in the process of manufacture. Such variations are now generally called tolerances and for all regular sizes and different fits complete tables of the tolerances have been elaborated by competent authorities to serve as a guidance when laying down the limits of tolerances for different parts of work. A piece of work does not consequently require to be made to the exact size laid down for it, but it can be allowed to vary in regard to size between certain limits.

There is, however, one condition that must be filled in order to make this system reliable, viz., that the gauges used have no errors in themselves, that certain variations from the exact sizes of the machine or tool parts can be allowed, and it

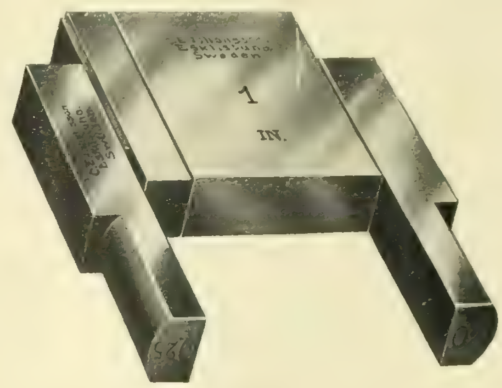


FIG. 2.

is only by measuring tools which give a true control of the tolerances admitted that the accuracy of machine parts can be simplified. The tolerances are usually given on regular work in 1,000ths or 10,000ths of an inch, so that it is evident the gauges must possess a still higher accuracy. For checking these gauges in turn, reference gauges are used which must be correct to a few 100,000ths of an inch, and in manufacturing such gauges it is needless to say great difficulties are encountered. Shop gauges, moreover, are subject to wear, and must be checked from time to time to ascertain that they are still correct, and consequently every engineer-

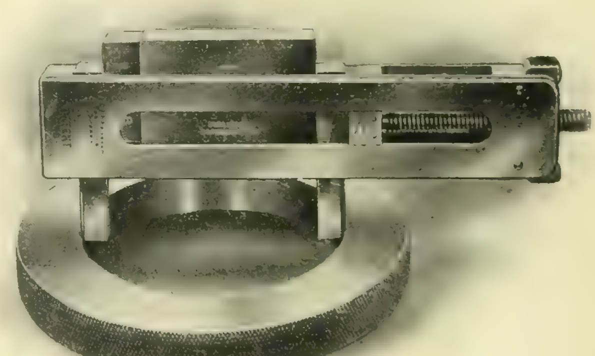


FIG. 3.

ing shop is obliged to be equipped with a number of checking or reference gauges. These checking gauges are of different shapes, some being cylindrical rods, with plain or spherical end surfaces, and others round discs or square blocks with spherical or plain parallel surfaces. The last shape is the most difficult to produce, but for exact measurements it is the most useful because it offers the necessary guidance, and cannot be used at an angle which with the other shapes is very difficult to avoid, as the size is determined only by points or lines.

All checking gauges, however, have the drawback that a set to meet all sizes required in an engineering workshop is expensive, and never able to meet the demand or need of new

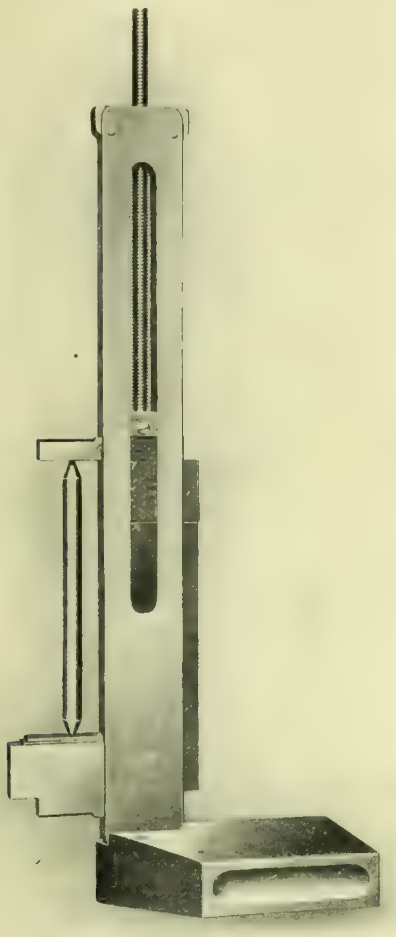


Fig. 1.

sizes completely. For this reason many engineering firms that otherwise are anxious to adopt only the best methods of manufacture hesitate to go to the expense of the necessary gauges, and feel obliged to be content with an inferior accuracy. For the same reason many manufacturers when designing a new machine, &c., consider the gauges they already have, and to conform to them often adopt sizes that are not the best. A further drawback with checking gauges supplied at different times to meet the particular requirements of the moment, is that they sometimes do not correspond to each other, especially if they are supplied by different makers.

To do away with all these drawbacks, and to supply once and for all a factory with all the gauges that are and might be required at any time, is the object of the Swedish "Johansson" combination standard gauges. This set of standard gauges consists of 81 pieces, and by using these separately or combined together, over 80,000 different sizes can be obtained, any of which sizes being accurate to within 0·00004in. at 62° Fah. This set is divided into four series, as follows: 1st series, 0·1001 to 0·1009 by 0·0001in.; 2nd series, 0·101 to 0·149 by 0·001in.; 3rd series, 0·050 to 0·950 by 0·05in.; 4th series, 1in., 2in., 3in., and 4in.

The blocks in the first series divide up the spaces between those of the second series, while the third and fourth series can be divided up by the first and second series; or, in other words, any size can be obtained from 0·2000in. up to 8in. or 10in., rising by 0·0001in. In addition it is possible to get the same size or combination in several ways. For example, 2·3769in. can be obtained as follows

A	B	C
0·1000in.	0·1001in.	0·1002in.
0·126in.	0·1008in.	0·1007in.
0·150in.	0·106in.	0·116in.
2·000in.	0·950in.	0·110in.
	0·120in.	0·250in.
	1·000in.	0·800in.
		0·900in.
2·3769in.	2·3769in.	2·3769in.

Although the composition of the "Johansson" set of gauges is simple, a series of conditions attach to their use that need to be carefully considered.

1. The measuring surfaces should be absolutely plain in order to admit the close approach of two gauges to each other when assembled.

2. The two measuring surfaces of one gauge should be absolutely parallel with each other, so that the end surfaces of a combination of a number of gauges remain equally parallel.

3. The degree of accuracy of each single gauge should represent the highest possible accuracy, so that the accuracy of any combination of gauges would be held or maintained which is necessary for checking purpose.

4. The accuracy of the single gauges should be proportionate to the nominal length of the gauge, that is, the smaller the gauge is, the higher should be the accuracy, so that a combination of a number of gauges has the same accuracy as a single gauge of a corresponding length; or in other words the combined gauge and the single gauge of the same length should be of the same degree of accuracy.

In the "Johansson" gauges these conditions are realised in a striking manner. The surfaces of the gauges are such perfect planes that when assembling two gauges they adhere to each other. The parallelism is perfect, and the accuracy

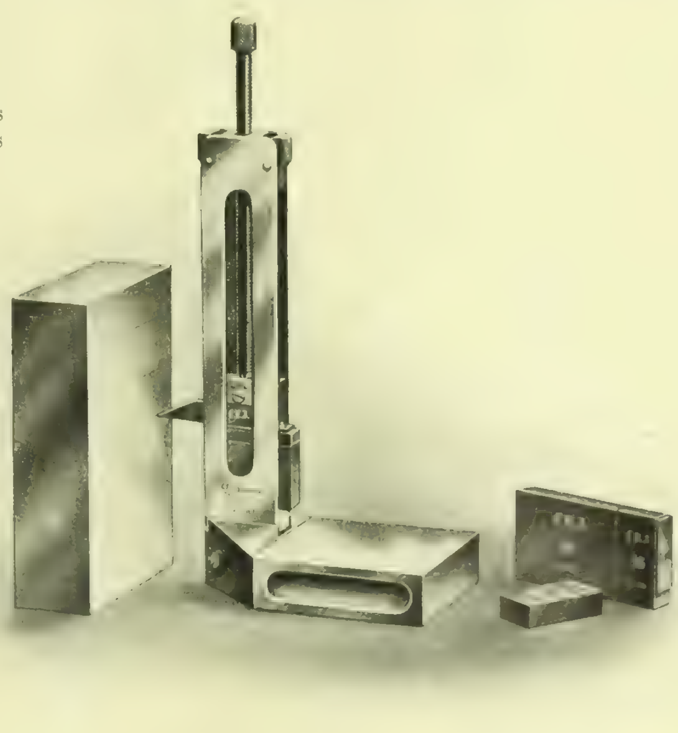


Fig. 5

can be easily proved by comparing different combinations making up the same size and testing them in a carefully adjusted snap gauge. This accuracy is the more remarkable in view of the large surfaces and the fact that they are brought out as a commercial article for daily use in the tool room.

It will be evident that in order to maintain an accuracy within the limits mentioned in a combination of a number of gauges the accuracy of a single gauge must be much greater. Comparisons made between different combinations of the

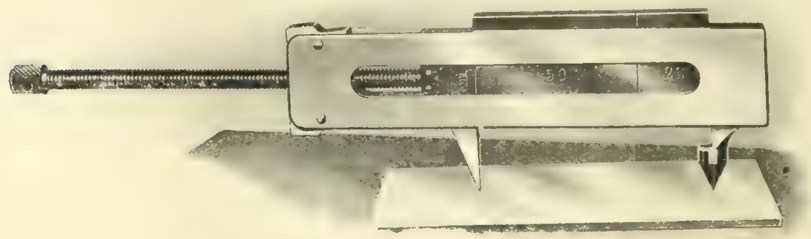


Fig. 6.

same size show that this accuracy is established throughout the set. The proportion of the accuracy laid down in the manufacture of the "Johansson" gauges is the $\frac{1}{100000}$ part of the length of the gauges. The small sizes consequently can always be reckoned to be exact fractions of the larger sizes.

Fig. 1 illustrates in a simple and practical way a method of proving the equal size of a combination gauge and a single gauge. The two similar size gauges are wrung to the surface of another gauge, so as to adhere. On the opposite surfaces of the two similar size gauges another gauge is wrung and it will be found that the latter adheres to both surfaces, which would not be the case if there was the slightest difference in size between the two gauges of the same nominal length.

To extend the use of the gauges to external measurements the "Points" illustrated in Fig. 2 are supplied.

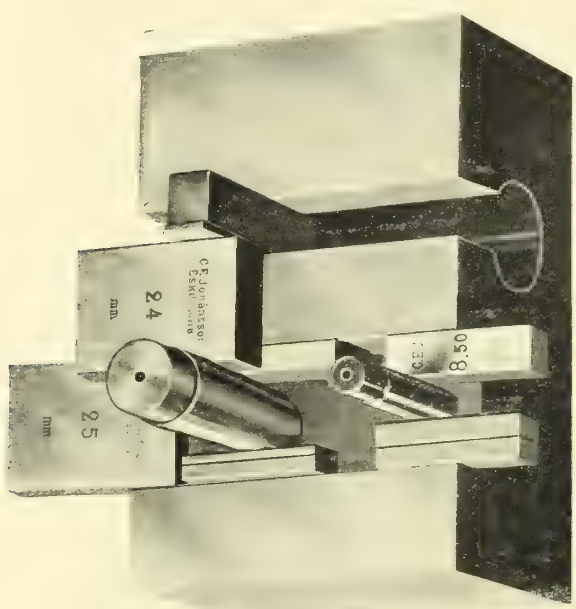


Fig. 7

These points are double the length of the gauges, and have one surface lapped to the same degree of accuracy and planeliness as the gauges. By wringing them over the end surfaces of a combination or a single gauge they adhere and form an exact "Snap" gauge. For half the length of the opposite points they are rounded to a certain radius, and by adding the thickness of these points, where radiused, to the size of the gauge or gauges between the points an accurate "Plug" gauge is made up. By this method "Snap" and "Plug" gauges can be made up of any or all of the sizes that are obtainable out of the complete set of blocks.

To facilitate the manipulation of these "Snap" and "Plug" gauges they can when required be inserted in a holder equipped with a split spring nut which enables the holder to be quickly adjusted to form a combined end, snap and plug gauge of the highest accuracy. Fig. 3 shows such a combination and a method of applying it.

When making fine measurements it is sometimes of importance that the gauges should not be touched by the operator, as the heat of his hands is liable to influence the size. In such cases the holder can be mounted on a foot as illustrated in Fig. 4, the foot being equipped with set screws to adjust the holder vertically. Figs. 5 and 6 illustrate combinations for scribing from a surface plate or from a centre.

The construction of jigs for repetition work is a field in which gauges of the kind under notice offer special advantages, and Fig. 7 shows a combination built up for this class of work.

In conclusion it should be stated that the agents for the gauges in this country are Messrs. C. W. Burton, copper and its alloys, and emphasized the points of greatest

POWDERED COAL FOR OPEN-HEARTH FURNACES.

In "La Metallurgie" M. Davidsen discusses his process for utilising finely-powdered coal as fuel in open-hearth furnaces, and which is proposed for preventing the heat losses of the regenerative furnace and avoiding the necessity of frequently varying the direction of the flow of air. The finely-powdered coal is burned above the metal bath. The advantages are thus stated: "All the heat contained in the coal is instantly developed in the furnace, and all losses in producing the gas in gas producers and preheating it are eliminated. A further advantage of the process consists in the method of communicating the heat to the metal. The flame produced by burning finely-ground coal consists of an extremely large number of minute incandescent particles having a high radiating capacity; there is therefore in the first instance no need to bring the surrounding air to the temperature of the coal particles, the heat being communicated by radiation, and not by convection, and in the second place the flame may be kept high enough above the metal bath to prevent its contamination by impurities from the coal, and that permits of doing away with the arch, which at best is only a source of trouble and expense. The temperatures obtained in such furnaces are claimed to be very high, closely approaching those of the electric furnace. By the elimination of frequent reversals of the direction of the flame various parts of the furnace are kept always at the same temperature. The rate of the flow of air must be large enough to prevent deposits of ash in the furnace proper."

COPPER AND ITS ALLOYS.

At a meeting of the Birmingham Section of the Institute of Metals, held at Birmingham on the 23rd ult., a paper, entitled "Notes on Copper and Copper Alloys," was read by Mr. F. Johnson. The author surveyed some of the investigations carried out in connection with copper and its alloys, and emphasized the points of greatest interest to the practical metallurgist. Commencing with the pure metal copper, he said it was well known of what enormous value to the electrical engineer had been the development of the electrolytic refining of copper, and the consequent high conductivity secured. In the place of the copper which was regarded as high conductivity copper before the days of electrolytic refining, and which rarely exceeded 98 per cent. conductivity, it was now possible to produce copper having a conductivity of 102 per cent. This increased conductivity was due to the increased purity, and producers of copper for use in electric work had to keep a constant watch on their metal owing to its great sensitiveness to the influence of impurities. Extremely minute particles of some elements were sufficient to lower the conductivity of copper to such an extent as to render its use in electrical work prohibitory. The lecturer described the influence of impurities on Muntz metal, and showed a number of lantern slides illustrating the defects and appearance of commercial alloys.

HIGH-SPEED BEARINGS.*

BY JOHN C. K. BALFRY.

WHEN considered in connection with the subject of this paper, the term "high speed of revolution" is somewhat misleading, for one should speak of the speed of journal surface rather than of speed of revolution. For example, take the case of a De Laval steam turbine, having a shaft 10 mm. diam. revolving at 30,000 revs. per minute, and compare the surface velocity of it with that of a steam turbine shaft of 100 mm. diam. revolving at 3,000 revs. per miuute. The surface velocity of each is about 51·6ft. per second, but the speed of revolution of the first is ten times that of the second.

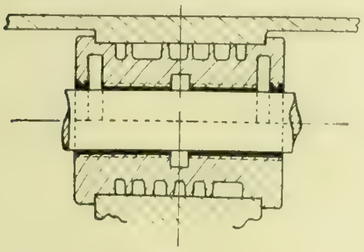


FIG. 1.

With rotary machines of the turbine or electrical kind, it may be considered that surface speeds of 50ft. per second are quite ordinary, and 100ft. per second are high. Pressures, per unit area of projected bearing surface, in common use with the kinds of bearings under consideration, are small when compared with those met with in modern railway practice, where 300lbs. per square inch of projected bearing surface is not at all exceptional in the case of driving axle journals, but the conditions under which these work are very different. Briefly, 50lbs. per square inch of projected bearing surface may be considered ordinary, and 90lbs. per square inch high for bearings of the class being dealt with.

Steam Turbine Bearings.—These may be grouped under three heads: (1) Rigid bearings; (2) swivel bearings; and (3) concentric ring bearings.

By a rigid bearing is meant one wherein the shell is held rigidly in the housing or pedestal surrounding it. It is adaptable where shaft deflection is very small, the slight slackness or clearance between the journal and the bearing, and also the presence of a film of oil around the journal being taken advantage of. Obviously these bearings are only of use where journal centres are comparatively small.

The swivel bearing is no doubt the most widely used kind in turbine practice to-day. Its name indicates one of its outstanding features. It is adaptable to practically all kinds of turbines and generators. It allows itself to radiate in the housing about its centre, thus accommodating itself to the

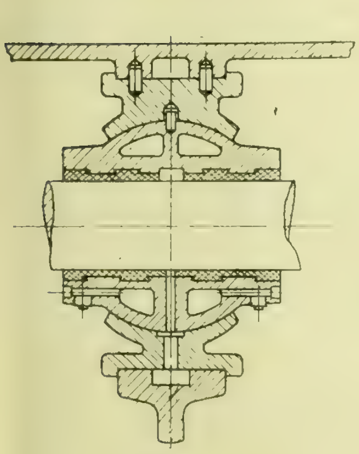


FIG. 2.

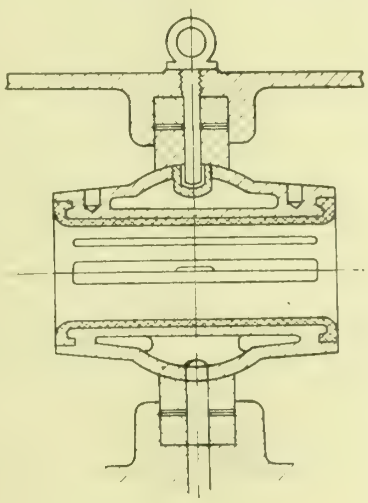


FIG. 3.

deflection of the shaft, so that its use with shafts having great length between journal centres is almost universal. It is easy to design the shell in such a way that lateral and vertical movement, required for alignment when bearings are being set at a considerable distance apart, is readily attained.

The concentric ring bearing has characteristics which are set forth in the description of it which appears further on.

* Paper read before the Rugby Engineering Society, February 4th, 1913.

The shell of the "rigid" type of bearing is usually made of good, close-grained cast iron, and is lined on the inside with white metal; Babbitt, Delta, or Magnolia metals are found suitable for this purpose. It is turned on the outside of the shell to fit the pedestal, in which it is prevented from rotating by means of dowels engaging in holes in the cap or cover of the housing; a flange at each end prevents end movement. There are, of course, other methods of preventing rotation and end movement, but the above is perhaps the simplest. If it is found necessary to water-cool such a bearing, the problem is much simpler than that which presents itself when the same treatment is desired for a bearing of the swivel type.

Fig. 1 represents a bearing of the rigid type. It is fitted to a 2,000 kw. steam turbine of the A. E. G. type. In this instance the shell is made of brass, and is lined with white metal. Among the interesting features it possesses may be mentioned that the oil, before being admitted to the journal, is passed around the space between the housing and the shell, to render the oil thinner before use. This appears to have a double effect on improving conditions of working—the shell is cooled by the circulating oil, and the friction losses in the bearing are reduced by the higher oil temperature. The surface speed of the journal is said to be 96ft. per second.

The swivel type is well represented here. Figs. 2, 3, 4, and 5 are specimens. Fig. 2 is used with a Melms-Pfenninger

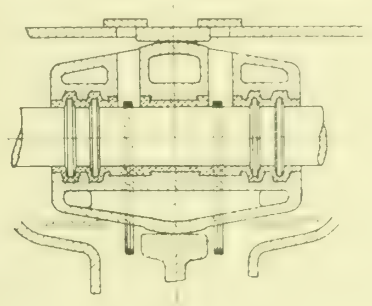


FIG. 4.

steam turbine of 3,000 h.p. at 1,500 revs. per minute. It is 180 mm. diam. by 380 mm. long, and the journal speed is 46ft. per second. The shell, which is made in halves, is of cast iron, and is lined with white metal. The temperature of the bearing can be kept below the danger point by circulating water through the chamber shown. A cage is provided giving ample bearing surface for the shell. The housing is, of course, on the outside, the cage being provided with lugs to prevent end movement. Dowels prevent cage and bearing from rotating. Oil is fed under pressure into the annular space in the housing, through a hole in bottom of both cage and shell, into a partly annular space around the journal.

Fig. 3 illustrates a bearing used with a 1,500 kw. 1,500 revs. per minute steam turbine, made by the Brush Electrical Engineering Company. The shell is hollow, and is lined with white metal. The diameter of journal is 5in. and length 15in. The bearing is capable of being easily aligned both vertically and laterally, shin plates being provided between the cage, which is immediately without the shell, and radial pads which are screwed to the cage. Both shell and cage are made in halves, and both are prevented from rotation in the manner shown, end movement being prevented by the flanges forming part of the housing. It is interesting to note that the oil, before being admitted to the journal, is passed through the hollow shell. Grooves arranged longitudinally and well chamfered on their edges are provided in the top half of the bearing surface. The surface velocity is about 33ft. per second.

The kind shown in Fig. 4 was fitted to a Zoelly steam turbine of 200 h.p. at 3,000 revs. per minute. It is of cast iron, lined with white metal. Lubrication is effected by six rings arranged in two chambers, containing three rings each. The bearing is water-cooled, water being supplied to and returned from the hollow shell through two unions screwed into top half of the shell; these are not illustrated. The ringed shaft is provided for expansion purposes, and keeps the shell and shaft always together. This bearing is [illegible]

diam. by 250 mm. long, the surface speed being 31ft. per second. Oil, after being carried to the upper surface of the journal by means of the rings, is distributed to the surfaces along grooves in the white metal. These grooves or channels "take in" at the top on both sides of the ring chambers and spread away spirally, returning again to the chamber further round the shaft. By this means an effective method of lubrication is obtained.

A bearing fitted to the steam turbines made by the British Thomson-Houston Company, Ltd., possesses several interesting features, among them being its "clean" finish and simple design. It consists of a cast-iron shell lined with Babbitt metal; the shell has spherical seats and the bearing is made in halves. Oil is delivered into a groove in the white metal and along the horizontal centre line, and is drawn down by the rotating shaft. On the side opposite to the oil inlet a second groove is provided, but it differs from the groove on the inlet side in being open at its ends, thus allowing oil that has passed under the shaft and has become heated to pass easily away at the ends of the bearing. Lubrication and cooling of the upper surface of the journal is effected by means of grooves leading from the inlet groove diagonally.

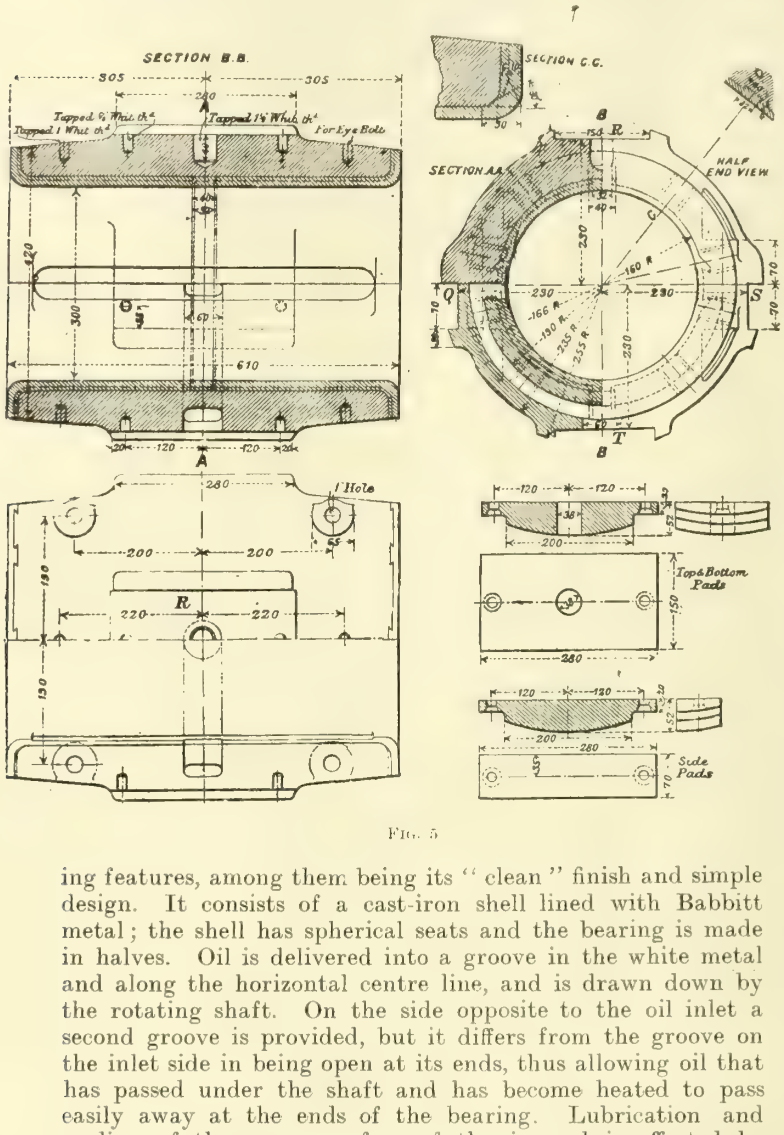


FIG. 5

Another bearing which has important characteristics is fitted to generator shafts at the exciting end of the rotor. When a turbo-generator is passing through a critical speed there is a tendency for the shaft to "whip." In order to destroy this action and ensure that the shaft will pass through a critical speed with absolute safety, the bearing sleeve is permitted a small amount of radial play between friction collars. This bearing is made in halves, and the radial side plates or collars are bolted in an elastic manner to the shell. It is made by the British Thomson-Houston Company, Ltd.

A bearing such as is fitted to turbines of 7,000 kw. capacity when running at 750 revs. per minute is illustrated, together with its accessories, in Fig. 5. It consists of a cast-iron shell to which is secured at four positions the pads which allow the bearing to swivel about its centre. The swivel pads are shown in the right-hand bottom corner. It will be seen that the shell is made in halves secured by comparatively small bolts and nuts. The interior is lined with white metal cast by the "Eatonia" process. The oil is conducted from the bottom of the shell along the two oil ways shown up to the horizontal centre line; there it feeds the two wide channels arranged on each side of the bearing. These channels are well bevelled at their sides and extend almost the whole length of the lining, and have a sealing piece at each end. These bearings represent a design which Messrs. Willans & Robinson, Ltd., have used on both large and small steam turbines.

In Fig. 8 is illustrated the well-known Parsons concentric ring bearing. It consists of a gun-metal sleeve in which runs the journal. The sleeve is surrounded by two or more gun-metal rings arranged in sets and separated by an oil or lantern ring. The whole is mounted within a heavy cast-iron outer sleeve to which the innermost sleeve is lightly secured at one end. This outer sleeve is spigoted to the housing only, and not to the cap, by means of a loose cast-iron half-ring which fits in the groove stem at the bottom. If it is desired to remove the bearing, the cap is first removed, and the half-ring rotated until it is free of the pedestal and bearing. It is then possible to slide the bearing endways off the shaft. There is a clearance of a few thousandths of an inch between the rings and sleeves. Oil finds its way into these spaces, and thus there is a hydraulic cushion which dampens those vibrations which are inseparable from shafts having high speeds of rotation.

The shells are made usually of good close-grained cast iron, but sometimes brass or gun-metal is used. The white metal lining is relatively thin and varies from about $\frac{3}{16}$in. thick in small bearings to about $\frac{7}{16}$in. for large ones. Some designers prefer to bore out the housing and the anchor grooving by which the lining is secured, whilst others rely on being able to get good castings. Whilst the machining out of the insides of the shells and anchor grooving may be a moot point in the sizes below, say, 2in. diam., it must be conceded that satisfactory results are obtained without machining in sizes above the figure given. In the design of the shell it is important to remember that the bearing must be capable of being removed from its place without the disadvantage of having to remove the shaft.

Anchoring of Lining.—To prevent "shake" in the comparatively soft lining, the latter should be well hammered into anchor grooves whether these are in the ends or in the cylindrical part of the shell. Almost invariably the dovetailed type of anchor is found in practice. They should be arranged so as to prevent both endwise movement and rotation inside the shell. After the white metal has been hammered into the grooves, the two halves may be bored to size, but the surfaces, even though machined as accurately as possible, will require bedding on to the journal.

Oil Grooves.—The arrangement of oil grooves is of first importance. They should lead away from the main source of supply to the bearing in a diagonally outward direction and with the direction of journal movement. This point is of importance where oil is used for the removal of heat, as well as for purposes of lubrication. The grooves should not be carried to the end of the bearing metal surface but stopped short, so that the flow of oil is checked and a partial seal formed by the bearing metal and the journal; the groove can then be led diagonally inwards, but with the direction of

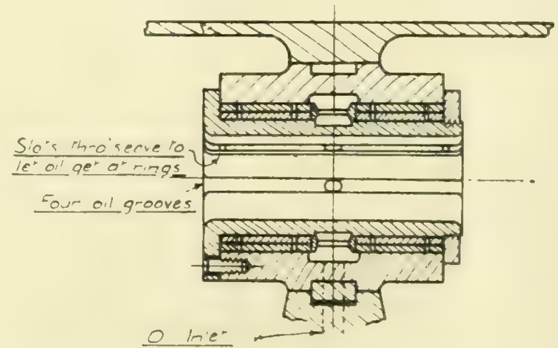


FIG. 6.

journal movement. These remarks would apply for both upper and lower halves of the bearing. If the oil grooves are carried quite to the ends of the bearing surface, there is a tendency for some of the oil to squirt out of the bearings without having done its quota of work.

Some makers do not consider that ramified oil channels of the type just described are necessary with forced lubrication, but these makers take care to lead the oil along almost the whole of the length of the bearing at or about the hori-

zontal centre line. These oil-ways should be gradually bevelled on the "off" side, in order that a thin wedge of oil may be formed between journal and bearing surface. If the edges of the channels on the "off" or "leaving" side are sharp, oil is peeled off the shaft as the latter revolves, thus rendering lubrication less efficient. In practice it is usual to

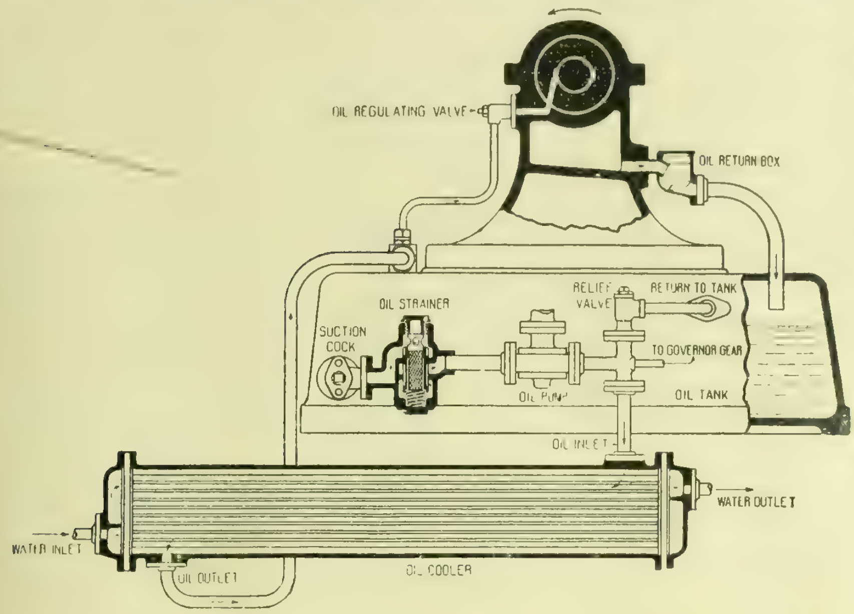


FIG. 7.

bevel both "on" and "off" sides in order to avoid mistakes in erecting.

Ring Lubrication. — This is a simple means of providing a bearing with oil. It consists of a ring or rings, the diameter of which is about twice the diameter of the shaft. The rings are rotated by frictional contact with the uppermost surface of the shaft. Oil clings to the surface, is raised by the rotating ring, and some is deposited on the shaft. The quantity of oil actually distributed to a bearing has been determined. Results published by Lasche show that the quantity of oil delivered varied very widely. Two bearings, the one split and lined with white metal, the other solid and of gun-metal, both of the same diameter and length, were tested together, the driving pulley being between the two. Each bearing was 90 mm. diam. by 260 mm. in length, and was provided with two rings, each 150 mm. diam. Exactly opposite results were obtained with the two bearings with reference to the quantity of oil passed through the bearings considered in connection with direction of rotation. With the gun-metal bearing, curves show that at from 1,500 to 2,500 revs. per minute the quantity varied from 1·2 pints to 1·9 pints per minute. The white metal bearings appeared to show the best results at from 1,500 to 3,000 revs. per minute, when from 1·1 to 3·1 pints per minute were actually given to the bearing. The rings were immersed 40 mm. below the surface of the oil.

One point is clear, however, that the maximum quantity of oil was distributed when the speed was from 23ft. to 46ft. per second, the theoretical velocity of the ring being from 14ft. to 28ft. per second. At higher speeds the oil supply began to decrease, it, no doubt, being thrown off the ring by centrifugal force. The exact quantity of oil given to a bearing by oil rings is doubtful, so much depending upon the exact condition of the machining of the shaft and of the ring, also the actual clearance in the bearings. The effect of ring immersion in the oil has been determined. Lasche states that the quantity of oil raised does not depend on the depth of immersion, providing this depth is not too small. Some authorities state that depth of ring immersion should be $\frac{D}{2}$, where D = diameter of shaft.

It seems unwise to depend upon the quantity of oil that will be persuaded to go through the bearing to do much towards cooling the surfaces, so that unless we can depend upon natural cooling, *i.e.*, by radiation, we must make use of artificial means for removing the [illegible] heat, *e.g.*, by water cooling the shell of the bearing. Where natural cooling is relied upon, let it be seen that the metallic contact between shell and housing is as ample as can be allowed. Oil grooves should be arranged to lead [illegible] from the source of supply spirally, the direction of the spiral being with the direction of shaft rotation. Oil rings should be carefully [illegible], especially on their insides, should be of a regular section throughout, and care should be taken that their movement is not impeded in any way.

Lubrication by Oil Under Pressure.—The author's remarks are confined to the bearings and to the lubrication of them, and are not intended to be so wide as to include a detailed examination of oiling systems. His remarks on this subject are consequently brief. This form of supplying oil to bearings may be said to be adopted when simpler means give an insufficient supply. Pressure can be given to the oil by providing an oil tank at a height of several feet above the level of the bearings, which tank is kept constantly full by means of a pump—direct connected to the machines, motor-driven, or worked by hand; the mode depending upon the conditions. From this tank cool oil is led to the bearings through a system of piping. Another way of obtaining pressure for the ingoing oil, and the one mostly adopted, consists in pumping the oil through a cooler to the bearings along a convenient pipe system. Fig. 7 shows a system of oil supply in use by the British Thomson-Houston Company.

The office then of the oil is two-fold—(1) to lubricate and (2) to abstract heat from the bearings. The oil should be delivered either at the sides or at the top of the journal. It should not be delivered at the very bottom of the journal, since in this vicinity the pressure of oil in the film greatly exceeds the pressure per unit area, as will be shown later.

Co-efficient of Friction. — When a journal runs in a well lubricated bearing upon a perfect film of oil, experiments show that the co-efficient of friction μ decreases with increase of pressure. Other quantities such as velocity and temperature, the latter especially, affect the co-efficient of friction. Attempts made to calculate the work lost by friction are futile unless we have a reasonably accurate figure for μ.

A curve is given in Fig. 10 which shows the mean of a number of Lasche experiments. It will be noticed that the co-efficient of friction μ, decreases very rapidly at first, but

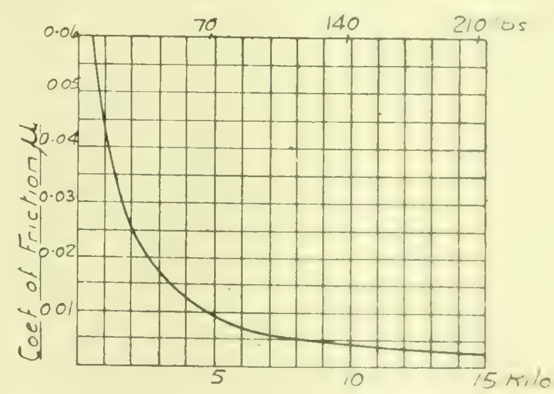


FIG. [illegible]

Influence of p on μ. Press. p lbs. [illegible] square inch [illegible] feet per second [illegible] with oil quantity [illegible] projected [illegible]

as the pressure is increased the curve becomes much flatter. Lasche noticed that $p \times \mu$ is very nearly a constant, and is taken as being such.

p = pressure per square inch of projected area (length of bearing × diameter of journal).

μ = co-efficient of friction taken on the whole circumference of the journal.

t = temperature of bearing [illegible] in Fahrenheit degrees.

v = velocity of journal in feet per second.

When $v=33$ft. per second, and when t is constant and equal to 122° Fah., $p \times \mu = 0{\cdot}568$.

The co-efficient of friction appears to be scarcely influenced by increase of velocity, within the range of the velocities indicated, 82ft. per second being the maximum. On the other hand, the temperature of the bearing bushes greatly affects the co-efficient of friction; this is shown by the curve in Fig. 9, which is self-explanatory. It is doubtless due to the fact that the warmer the oil the less its viscosity, and hence there is offered less resistance to shear of the oil film between the journal and the bush. Dewrance recommends that t should not exceed 200° Fah.

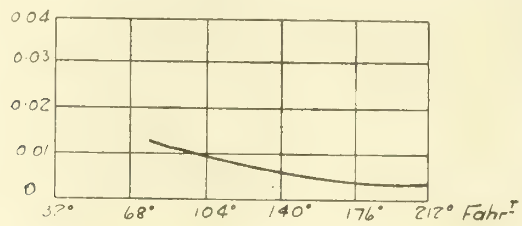


FIG. 9.

P 92lbs. per square inch. V 32·8ft. per second. Oil 0·005 galls. per minute per square inch of projected bearing surface.

Both an increase of pressure per unit area and a concomitant increase of temperature have, within limits, considerable effect in reducing the co-efficient of friction, much more so than when each acts singly. An excessive pressure causes the oil film to be squeezed out from between the journal and bush. If the oil is too warm, it possesses insufficient "body" to prevent its being squeezed out of the bearing.

It is very difficult to state when the oil film becomes broken down due to pressure and velocity, but it is easier to define the limits within which oil should be supplied to a bearing, and the maximum allowable temperature at which oil may be allowed to leave the bushes. In Fig. 10 is given a curve which shows the effect of temperature on viscosity of oil. It is taken from the Proceedings of Institution of Mechanical Engineers, Pullen and Findlay, 1909. The commercial viscosity is given by the formula:—

Viscosity $= 0{\cdot}205\ T\ \delta$.

T = time in seconds for 50 cc. to flow out of a Redwood viscometer.

δ = specific gravity of the oil.

It seems then that from a consideration of the foregoing remarks, that the total friction work in a particular bearing can be reduced by shortening it. But here one enters dangerous ground, for the manufacturer has to consider much more than frictional losses and the safe running of the machine at normal speeds. He has to think of the stilling of such vibrations as are set up in the shaft when the latter is passing through a critical speed, as well as a possible reduction in oil supply (this depending upon the lubrication arrangements) when the speed of the shaft is declining.

Pressures.— As stated in a previous paragraph, the ordinary pressures to-day are from 50lbs. to 90lbs. per square inch of projected bearing surface. In the discussion on a paper read before the American Society of Mechanical Engineers by Prof. Christie, it is reported that Prof. Hodgkinson remarked that 80ft. per second and 100lbs. per square inch were commonly employed, and he saw no reason why these velocities and pressures could not be materially exceeded. This to some extent agrees with Lasche's experiments, for within fairly large limits $p \times \mu$ is practically constant.

Velocities. — As already stated, present-day practice with bearings of this kind rules that velocities should not exceed 60ft. per second. As μ increases but slightly between 30ft. per second and 80ft. per second, there is little fear that a moderate increase on the higher figure will have any ill effect on the bearing, providing that the temperature is not allowed to rise too high and vibration is not forgotten. Allford's work on "Bearings and their Lubrication" contains a curve, showing the relation between pressure and velocity, used by the General Electric Company, of America, for perfect film lubrication. The following are readings taken from the curve.

V. in feet-seconds.	p = lbs. per square inch.
20	167
30	190
40	208
60	229
73·5	235

From the above it will be noticed that with increase of velocity, there is likewise an allowable increase of pressure. Lasche shows that within the limits of his experiments, with v and t constant, the increase of pressure was accompanied by a decrease in μ. Therefore since $p \times \mu \times v$ = friction work per square inch of projected surface, the friction work is only affected by variation in velocity. These deductions are to a certain extent borne out by data taken from the G.E.C. curve.

Many turbine builders assume that for running speeds μ is a constant quantity and is left out of account in determining the size of a bearing. The determining factors are then the product of pressure and velocity, $p \times v$ varies from 2,500 to 5,500, but in the latter product water cooling is resorted to by some builders.

Oiling.— With pressure or pressure-head systems, oil is admitted to a bearing usually either at the sides or at the top. Each system has its advocates, and it is well to remember Beauchamp Tower's classical experiment before attempting to admit oil at other places. Tower showed that the maximum pressure per unit area in the oil film was about twice as great as the calculated mean pressure per unit area on the projected surface of the bearing. Osborne Reynolds has shown, and others have confirmed, that the position of the shaft within the bearing varies with increase of load, and that the point of maximum pressure, which is on the "off" or leaving side, and not on the "on" side, as is sometimes supposed, moves up the "off" side of the bottom half of the bearing and back again to the bottom as the load is increased. For example, imagine that a shaft is rotating in a counter-clockwise direction within a bearing, the end view of which is presented towards the reader. The shaft, whose weight compels it to run on the bottom half of the bearing, rotates at first in the lowest position. Using

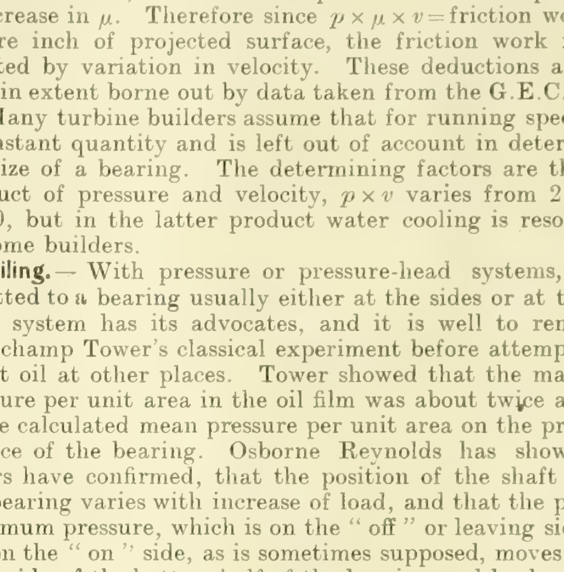


FIG. 10.

the four cardinal points to simplify matters, the shaft rubs first at S., with increase of load it gradually mounts up to E, dropping to S.E. as the load is still further increased. It is useless, then, to attempt to pump oil between journal and bearing surface anywhere between S. and E. We therefore admit oil at N., W., or S.W., these being the most convenient places.

Professor Goodman has shown that a reduction of the arc of "contact" of the bearing surface on the journal greatly reduces frictional losses in the bearings. An inspection of Fig. 5 shows that this fact has been taken advantage of by the re-

duction of the effective bearing surface on the bottom half by the well-bevelled oil channels at the horizontal centre lines.

The quantity of oil to be delivered to a bearing surface is proportional to its projected area. The following table gives the practice of three leading turbine builders:—

Gallons per square inch per minute.	Oil pressure in lbs per square inch
0·05	45 to 60
0·05	5 to 10
0·01	—

If p = say 60lbs. per sq. inch on the projected area.
μ = co-efficient of friction = 0·025.
v = velocity in feet per second, say 60 feet.
$p \times \mu \times v$ = work done in ft. lbs. per sq. inch per second.
$60 \times 0{\cdot}025 \times 60 \times 60 = 5{,}400$ ft. lbs. per minute.

Taking specific heat of oil at 0·4, and sp. gr. as 0·88
Q = gals. delivered per square inch per minute = 0·45.
T_1 = temperature of inlet oil, Fahrenheit.
T_2 = temperature of outlet oil, Fahrenheit.
$10 \times 0{\cdot}88 \times 0{\cdot}4(T_2 - T_1)Q$ = $B.Th.U.$ taken up by oil in passing through bearing per pound of oil delivered.

With $T_2 = 130°$ Fah. and $T_1 = 100°$ Fah. B.Th.U. per minute, capable of being taken up by the oil, is 47·5 = 37,000 ft.-lbs. per minute. As the journal only generates 5,400 ft.-lbs. of friction work per minute per square inch, we see that there is more than sufficient oil to keep the temperature of the bushes low.

The effect of shaft vibration has to be remembered, and it is more than probable that if this happens to be excessive, much more heat is generated through vibration than by friction due to p, μ, and v only.

The selection of a suitable oil is of importance. Great viscosity means loss of power, μ being greater than with small viscosity. Provided that complete lubrication is obtained, the thinnest of oil that will do the work will prove the most economical. The following results were obtained on a Sternol patent oil testing machine at a pressure of 100lbs. per square inch at 1,000 revs. per minute. Duration of test was 55 min.

Oil No.	Relative Friction at Beginning.	Relative Friction at End.	Temperature at Beginning. Deg. Fah.	Temperature at End. Deg. Fah.
4	1·45	0·9	68	107
5	2·8	1·25	68	126
6	3·75	1·5	68	132

The curves from which the above were taken fall very gradually. The effect on the relative co-efficient of friction is shown with the temperature rise, the most suitable oil of the three being No. 4, which has the lowest co-efficient of friction and lowest temperature rise.

In the following table results of tests on three turbine oils are given; they were obtained with the same machine as were the previous ones at 1,000 revs. per minute.

Oil No.	Relative Friction at Beginning.	Relative Friction at End.	Temperature at Beginning. Deg. Fah.	Temperature at End Deg. Fah.
1	1·8	0·3	86	147
2	5	1·15	86	147
3	6·5	1·25	86	147

No. 1 gives the lowest co-efficient of friction at all temperatures from 86° Fah. to 147° Fah. It will be noticed that the oil is colourless, and is therefore as free from impurities as it is possible to get it. The comparative thickness of these last three lubricants at various temperatures is indicated in the third column. According to tests made on the Sternol oil testing machine the quantity of oil required varies according to the quality of the lubricant. It is not correct to say that by using a cheaper oil one may use more of it, for if the oil is put on in very large quantities μ is not reduced whatever.

No. 1 oil—Thin, colourless.
„ 2 „ Green-golden, somewhat heavy.
„ 3 „ Heavy, golden.
„ 4 „ Thin, golden.
„ 5 „ Deep golden, medium.
„ 6 „ Golden, medium.

In ordinary turbine practice oil is delivered to the bearings at from 100° Fah. to 120° Fah., and returned at from 130° Fah. to 150° Fah.

Radiation.—Lasche has shown that the quantity of heat radiated from a bearing depends upon the extent of the surface exposed to the lower temperature of the surrounding air. Thus a bearing having good metallic contact with a large housing will be able to get rid of a great deal more friction heat than will one that is itself in contact with the cooler surrounding atmosphere. In Fig. 11 is shown a curve indicating the amount of heat, expressed in foot pounds, that may be expected to be dissipated into the surrounding air per second per square inch of projected area.

If W_r = work which bearing can dissipate in foot lbs. per second per square inch of projected area, t = temperature difference in Fahrenheit degrees, this curve can be closely represented by the equation

$$W_r = \frac{(t + 31)^2}{3{,}200}$$

This curve may be used when the bearing in question has a relatively thin housing, and is located in still air. If the

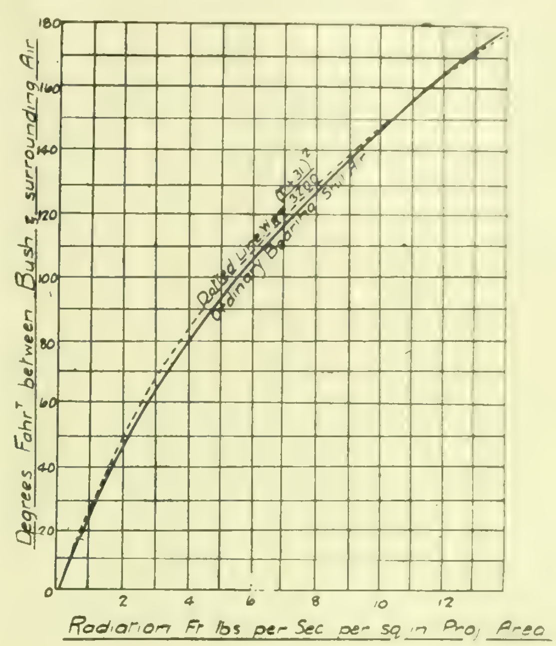


FIG. 11.

bearing is situated in a draught, *e.g.*, close to rotating armatures, the right-hand side of the equation may be multiplied by two.

The following table gives the composition of some of the best known anti-friction alloys.

	Copper.	Lead	Antimony.	Tin	Iron.
White metal	—	87·92	12·08	—	—
Delta metal	92·39	5·1	—	2·37	0·007
Magnolia metal ...	—	83·55	16·45	—	—
Babbitt metal	8·3	—	8·3	83·4	—

By the use of the "Eatonia" process in the casting of ordinary white-metal linings for bearings, the bearing surface is rendered much more dense, the molecular construction is much finer and there is an absence of segregation. Experiments to show the comparison between a bearing lined with white metal and another of the same size also lined with white metal but "Eatoniased," indicated that under exactly similar conditions the former seized up when the temperature of the oil bath rose to 137° Fah., the latter showed no signs of seizing even at 149° Fah. The pressures were 1,000lbs. per square inch in each case, oil bath lubrication was used, and the journal speed was nearly 8ft. per second.

Ball Bearings.—The ball bearing in its various forms has been used with electric generators and motors for some time, not only with light but with heavy machines. Up to the present this form of bearing has not found favour with turbine

builders, nor, generally speaking, with generator makers. It is no doubt due to fear of ball breakage through vibration at the critical speeds of the shafts, and the knowledge of the disastrous consequences which such failure would produce, that turbine makers have not advanced in their adoption of ball bearings. Since ordinary turbine shafts revolve at speeds between 1,000 revs. per minute and 750 revs. per minute, and weigh from one ton upwards, the weight to be carried at these speeds are consequently high.

It is probable that the first cost, bearing for bearing, is greater in the case of the ball type than with the friction type, but the lubrication arrangements of the former are insignificant when compared with those of the latter. The oil consumption is very small indeed with balls, and the co-efficient of friction at starting is about the same as running, this being approximately 0·002 to 0·003. It is recommended that for high speed ball bearings a somewhat thinner oil be used, and a little more of it than would be necessary with slow running ball bearings. The oil used should be of a non-corrosive nature, and free from impurities, especially those likely to act with the oil and produce results in the same way as fine emery powder or even chalk would be expected to do.

After a bearing suitable to the load, speed, and general conditions has been selected, the three most important points to bear in mind are: (1) accurate fitting; (2) correct alignment; (3) protection from dirt and moisture.

With most makers the load (corresponding to the speed), that a ball journal bearing suitable for a horizontal shaft, may be said to vary inversely as the cube root of the speed, or expressed in algebraic form.

$$\text{Safe load} \propto \frac{1}{\sqrt{\text{R.P.M.}}}$$

For thrust bearings:—

$$\text{Safe load} \propto \frac{1}{\sqrt{\text{R.P.M.}}}$$

In conclusion the author wishes to thank those friends who have kindly assisted him in the compilation of this paper, also Messrs. The British Thomson-Houston Co., Ltd.; Messrs. Willans & Robinson, Ltd.; Messrs. C. A. Parsons & Co.; Messrs. Fraser & Chalmers, Ltd.; Messrs. The Hoffmann Manufacturing Company, Ltd.; Messrs. The Stern-Sonneborn Oil Company, Ltd., for the loan of blocks, &c., particulars and data.

A SINGLE-PHASE MOTOR WITH POLE-CHANGING WINDINGS.

At a recent meeting of the Scottish Local Section of the Institution of Electrical Engineers held at Glasgow University, a paper by Messrs. J. S. Nicholson and B. Parker Haigh on "A Single-phase Motor, with Pole-changing Windings," was read by the authors, who described a new type of single-phase commutator motor which was recently installed in the Engineering Laboratories of the University. It was pointed out that the motor was essentially a new kind of railway motor designed to overcome some difficulties of the single-phase motors used in the high-pressure railway systems. Those systems had found more application abroad on account of longer distances that had been attempted. The feature of the motor described was that the windings were arranged for two numbers of poles, which gave better conditions for starting. It had also been designed specially for experimental work for senior students. The tests that had been carried out showed that the motor was more suited for the multiple-unit system than for large locomotives. A demonstration of the motor was afterwards given in the laboratory. It is of 10 h.p., direct coupled to a generator mounted on ball bearings to act as a brake and to measure the output of the motor.

Personal. — The Council of Sheffield University have appointed Mr. F. E. Armstrong, M.Sc.M.Eng., A.M.Inst.C.E., to the Professorship of Mining in the University in succession to Professor Hardwick.—The Mersey Docks and Harbour Board have appointed Mr. Thomas Monk Newell engineer-in-chief to the Board at a salary of £3,500. Mr. Newell was engineer-in-chief of the North-eastern Railway Company for the docks at Hull, Hartlepool, and Middlesbrough.

OIL ENGINES FOR MARINE PROPULSION.

The present position of the oil motor was discussed by Prof. W. Ripper in the course of a lecture delivered at the Sheffield University on Saturday last. Considerable progress, he said, was being made with the oil motor as a means of propelling marine vessels, and it was predicted by some that this engine was destined to supplant every other form of marine motor, but such a prophecy was, to say the least, very premature in the present state of our limited experience. It seemed more reasonable to say that the oil engine would make rapid progress as the motor for the cargo boat of the future, as the most economical type for the smaller class of vessels, but for the large power express liners or for battle-ships their introduction was a long way off. The large power oil motor was almost non-existent at present. All our experience as to its capabilities and limitations had yet to be acquired, and there would be many a costly bill to pay for experiment before such experience had been acquired.

There were many persons full of an immediate expectation of a coming oil power battle-ship which would sweep everything before it, but for such a ship to be built at the present time without that confidence which came from sufficient experience, would be a far greater and more serious anxiety to the country that built her than she would be to that country's enemies. In the steam-powered battle-ship we had absolute confidence; with the motor-powered ship we had everything yet to learn. Recently an attempt was made to fit a 12,000 h.p. battle-ship—not in this country—with oil motor machinery. The motor was to have six cylinders. In other words, 2,000 h.p. was to be generated in each cylinder. In a test of three cylinders of this engine an explosion occurred which wrecked part of the engine, killed several men, and caused a serious fire, and the vessel for which this engine was intended was now to be fitted out with a full power steam turbine plant.

The internal pressures in the cylinders of the Diesel type of oil motor, and the internal stresses in the cranks and other moving parts, were excessively high. There was a compression in the cylinders of at least 500lbs. per square inch, which was a pressure at least two and a half times as great as that in the high pressure cylinder of reciprocating steam engines. The temperatures also were very much in excess of anything to be found in steam engine practice, even with highly superheated steam. It was not, therefore, very likely that cylinders would be used for such pressures other than of quite limited diameters, and therefore of a restricted possible horse-power per cylinder. Assuming 1,000 h.p. per cylinder to be a practical proposal, then the maximum power which could be obtained from a Diesel motor plant on board ship was limited by the number of such units as the space available for power could reasonably accommodate. If, for example, six sets were fitted on each shaft in a twin-screw ship, then a total of twelve cylinders and 12,000 h.p. represented the total maximum power possible, but this was far removed from the 70,000 h.p. steam turbine sets of the "Lusitania" and other coming ships, which, if replaced by oil engines of 1,000 h.p. units, would require seventy such engines with all their complexity of cranks, valves, and other moving parts, to drive the ship which was now driven with such perfection by a simple, compact, and thoroughly reliable steam turbine plant.

This statement, however, was not intended to depreciate the high merit of the Diesel type of motor for smaller powers. The advantages of this motor were that the weight of fuel required was only one-third or one-fourth of that for a steam plant of similiar power, and as there were no steam boilers required with the Diesel motor a large saving of labour costs, as well as space, was effected. The principal disadvantages were that the cost of suitable oil was at present about three or four times the cost of coal, though this, it was hoped, might be remedied as new sources of oil supply were discovered. The cost of building the Diesel engine was at present much greater than the cost of an equivalent power in steam engines, and amounted in fact to as much as the cost of steam engines and boilers put together. It was expected that with time and experience these costs would be considerably reduced.

INDICATORS.*

BY JAMES G. STEWART.

(Concluded from page 122.)

Mechanism of the Hopkinson Optical Indicator for Recording the Displacement of the Engine Piston.—The errors of this mechanism, with its indicator gear as fitted on the Premier research gas engine,† were found to be so little affected by large variation in the forces applied to it that errors in it caused by inertia or yielding of the indicator gear may be neglected. The very large weight of $22\frac{1}{2}$lbs. hung to the end of the indicator lever caused a deflection of the spot of light of less than $\frac{3}{100}$in. In a kinetic experiment a weight of $3\frac{1}{4}$lbs. was bolted to the end of the indicator lever. A diagram of compression followed by expansion without explosion was taken and was compared with one taken under the same conditions, but without the weight on the lever. As weak a spring as possible was used, but no difference could be detected between the two diagrams. The "displacement" motion, however, was not accurate. Two large errors in the optical mechanism which affected the accuracy of both the "pressure" motion and the "displacement" motion were found. One of these was due to too large angular motions of the beam of light. The other was more serious; it was caused by the mirror being placed too far from the axis of rotation and resulted in lines of constant pressure being more open at one end of the plate than at the other. The pressure scale was therefore different for different positions on the plate. This, coupled with the fact that lines of constant pressure were not straight lines, makes correction of the diagrams from this particular indicator too tedious to be worth the labour involved, even if it had not exhibited the defect of Fig. 13.

The Correction of the Diagrams of Prof. Burstall's Crosby-Hopkinson Comparison Tests.—As the results of Fig. 10 were obtained from the particular Crosby indicator and spring used by Prof. Burstall, these results are applicable to the correction of his Crosby diagrams. Mention has already been made of tests which demonstrate that vibration of the engine is ineffective in relieving the indicator of its friction even when recording a constant pressure. In the case of a rising or falling pressure, vibration is still less effective, and its reduction of the friction becomes negligible. The pencil will therefore lag behind throughout expansion and compression by an amount proportional to the friction shown on Fig. 10.

The correction has two effects: (1) It reduces the mean pressure; (2) it alters the form of the expansion line. The corrected mean pressures have been worked out, and the errors between these and the Crosby and Hopkinson values are stated in Table II. Roughly, the Hopkinson indicated mean pressures are 6 per cent. too high, and the Crosby indicated mean pressures 3 per cent. too high.

TABLE II.—*Errors in Mean Pressures.*

Diagram Number.	Mean Pressure by Crosby Ind. Kg. per cm.^{2}	Percentage Errors in Mean Pressures.	
		Crosby.	Hopkinson.
1	5·375	3·4	6·2
2	6·34	3·0	6·9
3	6·60	2·9	4·4
4	7·06	2·9	6·2

The comparison tests showed very clearly a difference in form of the two expansion lines. Towards the beginning of expansion there was almost coincidence of the two lines, while towards the toe of the diagrams the Hopkinson indicator in every case showed a higher pressure than the Crosby. At the time this peculiarity was not explainable, but the author believes that a satisfactory explanation can be based on his experiments. There are errors in both indicators. The correction of the expansion line of the Crosby diagram, in accordance with the results of Fig. 10, lowers the expansion line by an amount which is comparatively large at the beginning of expansion and becomes small towards the end. The corrected expansion line is throughout its length lower than that obtained from the Hopkinson indicator, and lower by an almost constant amount, with a tendency to be greater at the higher pressures. Although the author had not access to the particular Hopkinson indicator and spring used in the comparison tests, yet the nature of the difference between the two expansion lines is an indirect proof of the presence in that indicator of an error of the same nature as that found in the Hopkinson indicator which he did investigate, an error caused by friction of the spring in its supports. The particular indicator used in the comparison tests was one lent by Prof. Hopkinson, and was certainly a high-class instrument of its type. It was undoubtedly much superior in all respects to the one which the author tested; in particular, it was free from the optical errors.

No correction has been made in the Crosby diagrams for errors in drum motion. With the care which was taken to ensure as accurate a drum drive as possible these were certainly very small, and as the diagrams were long and the engine speed only about 160 revs. per minute their effect may

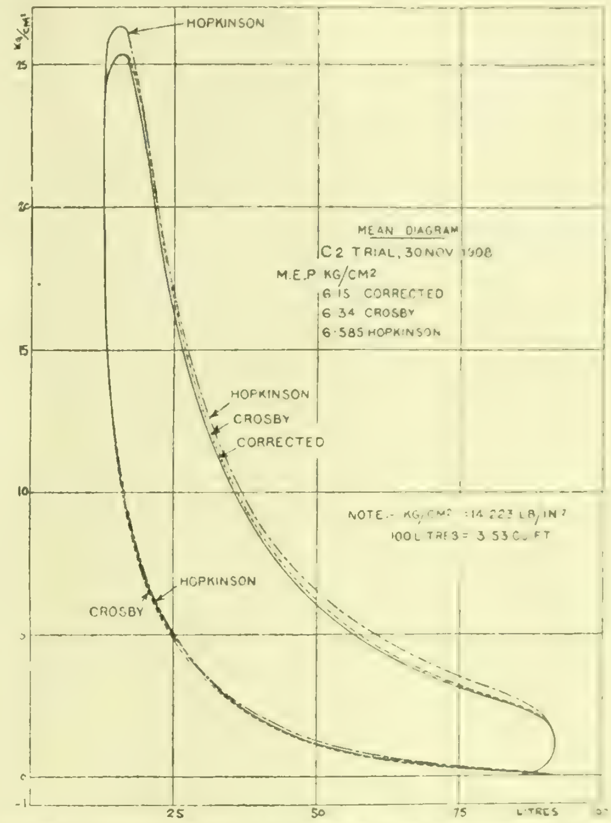


FIG. 18.—CORRECTION OF MEAN DIAGRAM OF PROF. BURSTALL'S C2 TRIAL.
(See Proc. Inst.M.E., 1900, page 790.)

be neglected without affecting the accuracy of the above deductions.

The author believes that the above correction eliminates indicator errors to within $\frac{1}{2}$ of 1 per cent. With such a degree of accuracy other sources of error become important, particularly errors introduced by defective sampling, by inability to measure the area of the diagrams to such a degree of accuracy. Also the rate of the spring, since its temperature is not known accurately, is only known approximately. These sources of error have already been discussed.

The method of calculating the correction was to divide the diagram into 16 parts and to scale off the pressures represented by the mid-ordinates of each of these parts and apply the correction to these. Going down the expansion line 16 values of the pressures are obtained: the correction for each is taken from Fig. 10, and the average taken. As the first $\frac{1}{16}$th of the stroke is roughly a period during which the pencil is in oscillation no correction has been applied to it. If oscillations of the pencil occur with change in the direction of motion of the pencil the mean line drawn through the oscillations gives an accurate statement of the pressure. If there is an oscillation but change in the direction of motion of the pencil does not occur, as is sometimes the case during the

* Paper read before the Institution of Mechanical Engineers, January 17th, 1913.
† Crosby-Hopkinson Comparison Tests. Proceedings I.Mech.E., 1909, page 785.

early part of the expansion stroke, the pencil does not oscillate about the true position, but lags behind an amount corresponding to the friction of Fig. 10. For these reasons the correction is applied to all parts of the stroke except the combustion period of the outward stroke (roughly the first $\frac{1}{16}$ of stroke). The average correction to the compression line is calculated in the same way, but here the correction is applied throughout the stroke. The sum of the two gives the total correction. This method of making the correction is the most accurate, as inaccuracies in measuring the pressure ordinates scarcely affect the final result. Fig. 18 is C 2 diagram of Prof. Burstall's tests, with the corrected diagram added for comparison.

The Design of Indicators.—A few principles, which should prove of value in the evolution of more perfect indicators, are deducible from these experiments:—

1. The spring must be held securely; there must be no variation in the nature of the support as in the Hopkinson indicator.

2. The piston rod, or whatever takes the resultant push of the piston, must be accurately in the axis of the cylinder, otherwise with pressure on the piston a constraining couple is introduced.

3. The resisting force of the spring must be a simple force acting along a line coincident with the axis of the indicator cylinder, and this must be true for all pressures. The commonest type of spring is the helical spring. If it be compressed the axis of its end bosses can only be kept coincident with the axis of the cylinder by the introduction of constraining couples. This is a cause of large errors in indicators, unless a double-coil spring be used. In the double-coil spring, if the spring is uniform no couple is introduced, but it is doubtful whether sufficient uniformity can be attained.

The design of no indicator recognises sufficiently the necessity to ensure only simple axial forces throughout the whole range of motion of the indicator piston. As workmanship can never be accepted as absolutely accurate, the design must be such that small inaccuracies in workmanship do not introduce large constraining forces and consequent large errors. Generally this will be secured by leaving the system as free as possible, and in particular by arranging that no unnecessary restraint is put upon the spring or the piston.

4. Mechanical linkwork is, as has been pointed out by Prof. Hopkinson, very unsatisfactory. Even when used with great care and with pins adjusted as well as possible, looseness in the joints cannot be avoided. This defect fortunately can be overcome in the optical indicator.

5. The periodic time of an oscillation must be small where rapidly changing pressures have to be recorded. This condition is best satisfied by the optical indicator.

6. The indicator drum is unsatisfactory for accurate work. It requires the use of cord or flexible wire, which introduces errors in the motion recorded. With the optical indicator this source of error need not be present.

7. On high-speed engines the optical indicator must be used, the inertia of the drum and pencil levers being too great; even if diagrams can be taken, that is no proof of their accuracy; in fact, and more particularly with regard to absence of oscillations of the pencil, the more imperfect indicators will give the smoothest and apparently best diagrams.

8. An indicator gear for an optical indicator requires in some respects special care. As the motion at the end of the indicator lever is very small, looseness in pins must be avoided; the play in them may be a considerable fraction of the whole motion. Also when a short lever is used care should be taken to avoid any slackness in pins which could result in a change in the effective length of the lever.

APPENDIX I.

Oscillations Damped by Forces of Constant Amount.

Let OX be the true line of pressure, Fig. 19. Let the pencil be given an initial deflection OA and then released. The pencil will then oscillate about its true position. Let the motion be damped by a frictional force of constant amount F acting on the piston.

$F = Oa \times$ scale of spring $\times$ area of indicator piston,
in which $Oa = Ob =$ indicated friction;
area of indicator piston $= \frac{1}{4}$ sq. in. for gas-engine indicator.

Consider the forces acting when the pencil is at the point P.

$$\text{Force exerted on piston by spring} = \frac{OP' \times \text{Scale of spring}}{4}.$$

$$\text{Net force exerted on piston} = \frac{\text{Scale of spring}}{4}(OP' - Oa).$$

$$= \frac{\text{Scale of spring}}{4} aP',$$

i.e., it is proportional to aP', and therefore the motion is simple harmonic about a position of zero force represented by aa.

At B the centre of the motion changes and falls on the line bb.

Since $aA = aB'$ and $bB' = bC'$ and $Oa = Ob$, it follows that

$$OA - OC' = 4 \,.\, Oa;$$

$$\therefore Oa = \frac{OA - OC'}{4}.$$

Friction in terms of pressure on indicator piston

$$= Oa \times \text{scale of spring}.$$

$$= \frac{OA - OC'}{4} \times \text{scale of spring}.$$

Similarly, $OC' - OE' = 4 \,.\, Oa$.

Also the periodic time of oscillation is constant, and con-

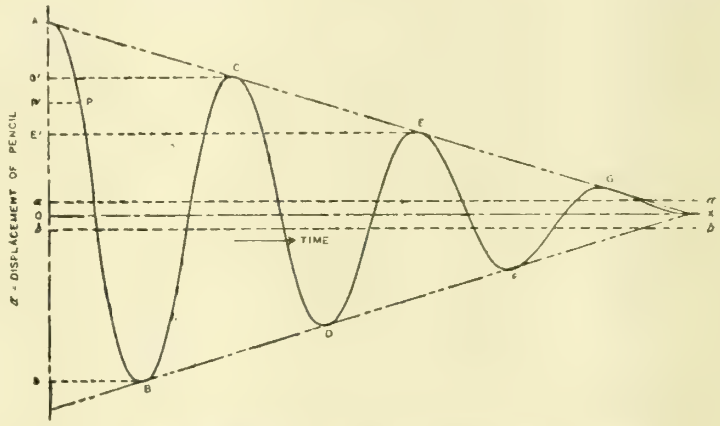


Fig. 19.—Diagram of Oscillations Damped by Forces of Constant Magnitude Opposing the Motion.

sequently the line drawn through ACE will be a straight line.

APPENDIX II.

The Calculation of the Periodic Time of an Oscillation of the Pencil.

In motion problems, when dealing with many parts having different motions, it is customary, for simplicity, to substitute when possible an equivalent system in which a mass concentrated at a chosen point has the same effect on the motion as the distributed mass of the real system. This "equivalent mass" will be supposed to be concentrated at the piston; its amount may be found in various ways. One convenient way is to calculate the kinetic energy of the system in terms of a chosen piston velocity, and to make the equivalent mass of such amount that its kinetic energy equals that so calculated. The equivalent mass of the real system is not constant for different positions of the pencil, but is sufficient nearly so for practical purposes. The value stated below is that for the position in which the pencil lever is perpendicular to the axis of the indicator cylinder. The calculation gives the mass at the piston equivalent to piston and pencil gear (Crosby heavy pattern type) = 55·8 grm. The coils of the spring do not all move with the same velocity. Their combined effect is the same as that of a mass of one-third of their mass, moving with and having the velocity of the piston. Table III. gives a statement of the equivalent mass.

Table III.

Scale of spring (gas indicator) ...	20	80	160	240
Equivalent mass of spring ... g.	2·2	2·9	4·5	5·2
Equivalent mass of piston and pencil gear ... ... g.	55·8	55·8	55·8	55·8
Total equivalent mass ... ... g.	58·0	58·7	60·3	61·0

With a knowledge of the equivalent mass it is simple to write down the equation of motion of the pencil, neglecting friction:

Let M = equivalent mass at piston (grammes).
R = rate of spring (dynes).
q = ratio of pencil travel to piston travel.
x = deflection of pencil from its position of rest (cm.).

For the Crosby indicator $q = 6$.

When the pencil deflection is x, the spring exerts a force in excess of that required to balance the pressure on the piston

$$R\frac{x}{q}.$$

The resisting inertia force $= M\frac{\ddot{x}}{q}$;

therefore, neglecting friction,

$$R\frac{x}{q} = -M\frac{\ddot{x}}{q},$$

i.e.,

$$M\ddot{x} = -Rx,$$

which is the equation of a simple harmonic motion, the periodic time of which is

$$T = 2\pi\sqrt{\frac{M}{(R)}}.$$

From this equation the periodic time of oscillation can be calculated when M, R, and q are known. There is no change in T if a solid frictional damping force is introduced.

APPENDIX III.

The Theoretical Correction of an Indicator Diagram.

Let M = equivalent mass at piston.
x = height of pencil above atmospheric line.
q = ratio of motion of pencil to motion of piston.
R = rate of indicator spring.
p = true pressure in indicator cylinder.
p_i = indicated pressure.
a = area of indicator piston.
F = force required at piston to overcome friction.

The equation of motion of the pencil will be

$$\frac{M\ddot{x}}{q} = -\frac{Rx}{q} + pa - F,$$

i.e.,

$$-\frac{Rx}{aq} + p = \frac{M\ddot{x}}{aq} + \frac{F}{a},$$

by dividing by a,

$$p - p_i = \frac{M\ddot{x}}{aq} + \frac{F}{a},$$

since

$$\frac{Rx}{aq} = p_i,$$

the indicated pressure.

$p - p_i$ is the error in the indicated pressure.

$\frac{F}{a}$ = the pressure per square inch on piston required to overcome friction. Its value has been determined, and is given in the Paper to which this is an Appendix.

If $\frac{M\ddot{x}}{aq}$ could be determined, an accurate correction could be made. Dr. Meyer, of Berlin, has given a similar equation to the above, except that instead of the term $\frac{F}{a}$ he has one $K\dot{x}$ making the resistance to the motion proportional to the velocity (see discussion of the nature of this resistance in paper). Assuming the drum motion of his indicators accurate and the rotation of the crank uniform, he deduced from his indicator diagrams the variation of x with time, and plotted these on a base of time. This curve he differentiated graphically, obtaining $\dot{x}$; a second graphical differentiation gave him $\ddot{x}$. M, q, and a were known, and therefore he obtained the value of the term $\frac{M\ddot{x}}{aq}$. To obtain more accurately the relation of x to time, he took, besides his ordinary diagrams, diagrams in which the drum motion was 90° out of phase with relation to its true position.

Dr. Meyer's method, however, is not at all satisfactory. A second differential, even if the differentiation is accurate, is liable to enormous errors resulting from small errors in the original diagram; but besides this source of error the differentiation by graphical methods is very far from accurate.

When oscillations occur they are generally the result of inertia, and correction is necessary, but rather than introduce large errors by attempting to obtain a second differential it is better to draw a mean smooth curve through the oscillations, and, accepting this as the diagram corrected for inertia, make a further correction for friction. This second correction can only be made satisfactorily for those parts of the diagram throughout which the pencil is either rising or falling. Lines of constant pressure cannot be corrected. Fortunately the most important constant pressure line—the atmospheric line—is also that in which the errors are least. It will be all the more accurate if just before drawing it the pencil is lifted momentarily off the paper.

THE DEVELOPMENT OF HIGH-SPEED STEEL.

An interesting lecture entitled "Recent Advances in Scientific Steel Metallurgy," was recently delivered by Prof. J. O. Arnold, at the Royal Institution. He first referred to the antiquity of steel, and pointed out that it must have been known to Homer and Boadicea. Records of 1160 proved that the monks of Kirkstead Abbey made wrought iron, and probably steely iron, at Kimberworth, near Sheffield. Chaucer mentioned Sheffield "Thywtels" in 1386, and Sheffield table-knives were then common. Peter Bales recommended, in 1590, Sheffield razors and penknives for cutting quill pens; but Hunter wrote, in 1615, that Sheffield only produced armour fit for the common men-at-arms, whilst knights obtained their armour from Spain and Italy.

After tracing the growth of the steel industry in Sheffield, Prof. Arnold dealt with the process of producing steel ingots by the fluid or crucible process introduced by Benjamin Huntsman, a clockmaker, of Doncaster, about the year 1740, and pointed out that this steel was not pure, though free from weld lines. Two slides were thrown on the screen showing two crucible steels, one poured in the "lively" condition and the other in the "killed" condition. The latter was quite solid, apart from a pipe, whilst the former was full of blowholes and much larger than the "killed" specimen. The blowholes contained hydrogen, nitrogen, and carbonic oxide under pressure, and could be removed by "killing," melting the metal with a trace (say 0·01 per cent.) of aluminium. Scientific explanations of this remarkable effect of aluminium could be found in text-books, but Prof. Arnold acknowledged that although he had studied the problem for the past 25 years he was no nearer a solution.

The first beginning of what might be called the tungsten-chrome era in cutting steel metallurgy was, he said, in 1870, when Robert Forrester Mushet, at the Clyde Works, Sheffield, began to manufacture on a considerable scale his "self-hardening steel." Mushet had practically discovered that when carbon steel was alloyed with a large percentage of tungsten it, when cooled from a yellow heat in a draught of air, was not only sufficiently hardened, but owing to the fortifying action of the tungsten on the carbon, its hardenite was also thermally considerably more stable than that of plain carbon steel. It was probable that in Mushet's early steels the "letting-down" point of the hardenite was raised to a temperature of perhaps 400° C., thus enabling engineers to take bigger cuts and work at higher speeds. Later, about 1880, Mushet still further fortified his hardenite by the addition of relatively small percentages of chromium, and between 1880 and 1900 self or air-hardening steels were produced by many steel manufacturers on considerable scale.

In 1900, the lecturer said, a profound sensation was aroused throughout the steel world when, at the Paris Exhibition in 1900, the Bethlehem Steel Company, of America, showed turning tools made under the alleged patent of Messrs. Taylor & White, cutting very mild steel at a speed which rendered the nose of the tool red hot. It was obvious that in these tools the thermal stability of the hardenite had been raised to perhaps 600° C. The chemical compositions in the patent embodied nothing which had not been included in the Mushet type of steel for a period of about 20 years before the date of the American patent. In fact, what Taylor and White had really done was to show that this type of steel was capable of retaining its cutting edge at a much higher temperature than most engineers and metallurgists had realised. For this demonstration every credit was due to the Bethlehem Company. Sheffield steelmakers, realising future possibilities, made from the year 1900 and onward a series of experimental researches, which eventually gave to engineers that astonishing material known as high-speed steel, in which the thermal stability of the fortified hardenite was raised to about 700° C. The claims of the Taylor-White patent formed the subject of protracted litigation, and in the end the United States Circuit Court pronounced it to be absolutely invalid. The lecturer and his late colleague, Dr. A. McWilliam, were commissioned to investigate at Sheffield University the accuracy or otherwise of the curve specified in the patent. They found that with a steel containing about 18 per cent. of tungsten, 3 per cent. of chromium, and 1·3 per cent. of carbon, the maximum efficiency number of about 5,000 was obtained at the lowest temperature 830° C., after which the higher the hardening temperature the smaller was the efficiency number, which at 1,300° C. had fallen to 500, or only twice the efficiency of plain carbon steel. In a similar steel containing, however, only 0·7 per cent. of carbon, the efficiency number at 830° C. was only about 500, but the efficiency steadily rose with the hardening temperature till at 1,300° C. it reached the astounding number of about 32,000.

While the year 1870 marked the beginning of the tungsten era, and 1880 that of the tungsten-chrome era, the years 1899 to 1902 inaugurated what was destined to be the most remarkable epoch of the three—namely, the vanadium era. During these years were carried out in the experimental steel works of Sheffield University a series of researches on the influence of the comparatively rare metal vanadium on plain carbon steel and on alloy steels, the most remarkable results of which were the following:—

(1) A plain carbon steel, containing about 1 per cent. of carbon, had a yield point of 35 tons per square inch, a maximum stress of 60 tons per square inch, an elongation of 10 per cent. on 2in., and a reduction of area of 10 per cent. The addition to such steel of about 0·6 per cent. of vanadium raised the yield point from 35 to 65 tons, and the maximum stress from 60 to 86 tons per square inch, still leaving an elongation of 7 per cent. and a reduction of area of 8 per cent.

(2) A steel containing 0·25 per cent. of carbon and 3·3 per cent. of nickel registered a yield point of 33 tons, a maximum stress of 42 tons per square inch, an elongation of 26 per cent. on 2in., and a reduction of area of 53 per cent. A practically identical steel, but containing in addition about 0·25 per cent. of vanadium, recorded a yield point of 50 against 33 tons, and a maximum stress of 68 against 42 tons per square inch, while the elongation was 17 per cent. on 2in., and the reduction of area 36 per cent.

(3) A steel containing 0·25 per cent. of carbon and about 1 per cent. of chromium registered a yield point of 27 tons, and a maximum stress of 41 tons per square inch, together with an elongation of 36 per cent. on 2in., and a reduction of area of 55 per cent. The addition of 0·25 per cent. of vanadium raised the yield point from 27 to 40, and the maximum stress from 41 to 55 tons per square inch. The elongation was lowered from 36 to 26, and the reduction of area from 55 to 53 per cent.

Thus vanadium differed from tungsten in having an almost magically beneficial effect, not only on cutting, but also on structural steels. In connection with vanadium steels it was an interesting fact that the series of copyrighted and published reports issued from Sheffield University during the years 1900 to 1902 were unconscious plagiarisms of a series of American patents issued during the years 1904 to 1908. This seemed to constitute a remarkable problem in psychology.

A study of vanadium steels made by the lecturer and Prof. A. A. Read, of the University of Wales, had yielded results of profound importance. Vanadium did not seem to form a double carbide with iron. It gradually wrested the carbon from the carbide of iron till when about 5 per cent. of vanadium was present Fe_3 C could not exist, and only a vanadium carbide $V_4 C_3$ containing 15 per cent. of carbon was present, this constituent being constant at any rate in tool steels containing up to 14 per cent. of vanadium. The micrographic analysis of these alloys had resulted in the discovery of three new constituents—viz., vanadium pearlite, vanadium hardenite, and vanadium cementite. Vanadium hardenite seemed to have a hardness of 8 (topaz) as compared with the hardness 7 (quartz) of iron hardenite. The recalescence results obtained were of great practical, as well as theoretical, interest. They strongly suggested the explanation of the curious thermo-mechanical behaviour of high-speed steels, and incidentally they appeared to prove provisionally that the hardening was not due to allotropic change, but to the carbon change only.

As regards the advance in the cutting efficiency of turning tools from 1740 to 1912, the best steel of this kind made in Sheffield in 1740 would be absolutely incapable of cutting at all under conditions under which the best modern high-speed steel would remove 700 cub. in. of metal before breaking down. The advantages of this enormous increase in cutting power were manifold. In 1909, the lecturer had suggested at the Royal Institution the coming of a new British steel, which would have a cutting power four times as great as the best steel then on the market. The skilful application of vanadium by Sheffield steelmakers had practically fulfilled that forecast, and the world-wide sensation and publicity created by the announcement had left Great Britain supreme in this very important branch of scientific steel metallurgy.

New Cruiser Classification.—An official announcement has been made to the effect that the Admiralty have decided to discontinue the use of the terms "armoured cruiser," "protected cruiser first class," "protected cruiser second class," "protected cruiser third class," "unarmoured cruiser," and "scout." In future there will be only three classes—"battle cruiser," "cruiser," and "light cruiser." The term "battle cruiser" is to retain exactly its present significance, but that of "cruiser" will cover "protected cruisers first class" as well as existing pre-Dreadnought armoured cruisers. The term "light cruiser" is to be used to designate the remaining vessels, including those which are at present classified as "scouts."

Fellowship Examination of the Society of Engineers.—The council of the Society of Engineers (Incorporated) announce that arrangements are being made for holding the fellowship examination of the society during the second week of June next. The compulsory theoretical subjects are:—Principles of statics and theory of structures; principles of kinematics and theory of mechanism; principles of dynamics and theory of machines; strength and elasticity of materials. One of the following subjects must also be taken theoretically: Chemistry, physics, hydraulics, geology, metallurgy, geodesy. At least one and not more than three practical papers have to be selected. The subjects suggested include: Water supply; canalisation and irrigation; sanitation, sewerage, and sewage disposal; mining; metallurgical engineering; marine engineering; heat engines; naval architecture; railway engineering; dock and harbour engineering; electrical engineering; telegraphy and telephony; gas engineering; warming, ventilation, and hot-water supply; structural engineering, reinforced concrete construction; the testing of machinery and plant; aeronautics. The council, however, are prepared to consider applications from candidates to be examined in other branches of engineering. Intending candidates should apply to the secretary of the society, at 17, Victoria Street, Westminster, S.W., for full particulars.

ILLUMINATION OF ENGINEERING WORKSHOPS BY GAS, ELECTRICITY, AND OIL.*

BY FRANKLIN THORP.

GAS.

THE lighting of engineering works has not until lately received the consideration its importance warrants, and as a gas lighting engineer I welcome this opportunity of indicating to some extent what can be accomplished by gas. I cannot do better than quote from the December issue of "The Illuminating Engineer" some simple rules for good lighting: (1) Don't work in a flickering light. (2) Don't expose the eyes to unshaded lights in the direct range of vision. (3) Don't judge illumination by the brightness of the lamps. (4) Avoid excessive contrast. (5) Use right type of globe, shade, or reflector. (6) Make sure that the illumination is sufficient. (7) Keep lamps, globes, and reflectors clean. (8) Make sure that lamps are in the right position.

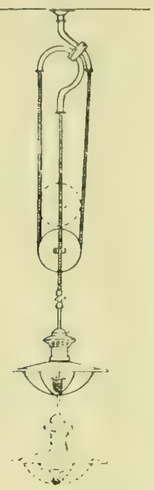


FIG. 1.

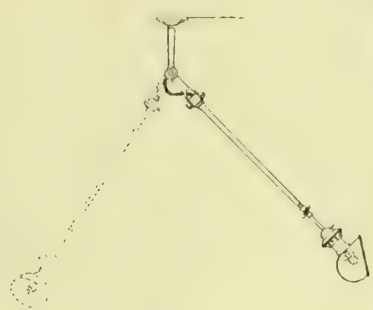


FIG. 2.

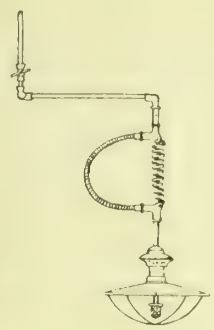


FIG. 3.

It is, of course, well understood that there are many ways of treating the subject, and a really satisfactory scheme could only be obtained by joint consideration between the manager of the works concerned and the illuminating engineer. The position of the various tools and class of work done must of necessity be taken into account, therefore, the scheme now presented is only one of many that could be devised, but I would mention that a similar scheme is giving every satisfaction at a large engineering works in Yorkshire. As a practical engineer myself, and being interested as director or consultant in various works and mills in Lancashire, I am a firm advocate of giving plenty of light, knowing that the increased production and superior quality of work done more than pays for the cost of extra illumination. Whilst I quite agree with basis of 1½ ft.-candles, proposed as a basis, it will be noticed that I have shown a much greater illumination.

This handicaps to a large extent "gas lighting," but having made the above statement, and given the reason for so doing, I am content to leave the matter in your good hands, confident that due allowance will be made. Considering the great progress that has been made during the last few years in gas lighting, I regret to say that I know of many engineering works (otherwise in every way up to date) where old flat flame burners are in use, giving two and three candles per foot of gas consumed, whereas with modern fittings some 50 candles per foot of gas consumed are regularly obtained. For the purpose of this paper, I shall take an efficiency of 50 candles per foot of gas consumed, as although this is greatly exceeded in laboratory tests, and also in many practical tests it is advisable to take a figure which can be maintained in actual practice.

The great increase in efficiency of gas lighting is due to the introduction of the incandescent mantle. The gas, instead of emitting light when slowly consumed, is burned as a non-luminous flame and used to heat up a specially-prepared mixture of the oxides of thorium and cerium. This preparation has the property when heated to incandescence of emitting a comparatively large amount of energy as light. I say comparatively advisedly, as it is only when compared with the flat flame that this is so, for whereas the increase in illumination is some 20 times, the actual luminous efficiency is only about 2 per cent. The efficiency of an incandescent mantle rises very rapidly with the temperature, and the efforts of the gas lighting engineer are therefore directed in raising the flame temperature. It is well known that the increase of radiation varies as the fourth power of the absolute temperature, but the increase in luminous efficiency is at a much greater rate. The following table will explain this:—

Absolute Temperature.	Hefners per square mm
1,764° C.	0·10
1,982° C.	0·50
2,092° C.	1·00

It will be noticed that at the temperature of a good Bunsen flame, viz., 1,982° C. absolute, the efficiency is 0·5 hefners per square millimetre, whereas at 2,092° C. absolute—a rise of only 110°—the efficiency is doubled. This is the explanation of the increased efficiency of modern high-pressure lighting. When the small actual efficiency we are even now obtaining is considered, I feel sure you will agree with me in saying that, although the present results are indeed very good, the possibilities before the gas-lighting engineer are still greater. I would at this point ask all interested in illumination to give this matter very careful consideration before installing any other system of lighting than that by gas; not only is it in front to-day, but the probabilities of further improvement are almost unlimited.

The main points for our consideration are: (1) Cost of installation. (2) Maintenance, which includes cost of gas, mantles, globes, labour, &c. (3) Suitability, which includes reliability, character and colour of light, steadiness, ease of manipulation, probability of improvement in efficiency, and adaptability.

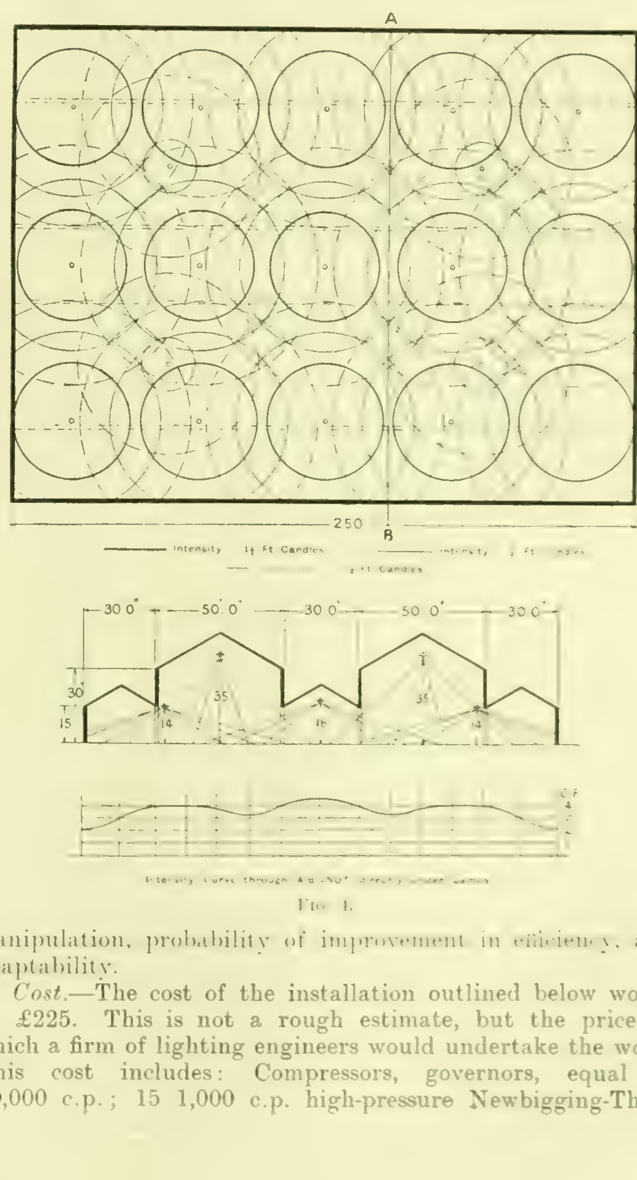


FIG. 4.

Cost.—The cost of the installation outlined below would be £225. This is not a rough estimate, but the price at which a firm of lighting engineers would undertake the work. This cost includes: Compressors, governors, equal to 30,000 c.p.; 15 1,000 c.p. high-pressure Newbigging-Thorp

* Abstract of papers read before the Manchester Association of Engineers, January 25th, 1913.

lamps, 16ft. high; 4 1,000 c.p. low-pressure Grætzin lamps, 35ft. high; 100 100 c.p. high-pressure textile lamps; 25 rise and fall pendants, Fig. 1; 25 universal joint pendants, Fig. 2; 50 anti-vibrating pendants, Fig. 3; all the necessary piping, taps, ironwork, and labour in fixing.

The compressors and governors are specially constructed to supply a constant mixture of about 90 per cent. gas and 10 per cent. air at a constant pressure to the lamps. The per centage of air can, however, be varied at will by the turning of a screw. The lamps are constructed to burn the mixture produced at the compressor, and the special feature of this lamp (which owes its origin to a discussion with reference

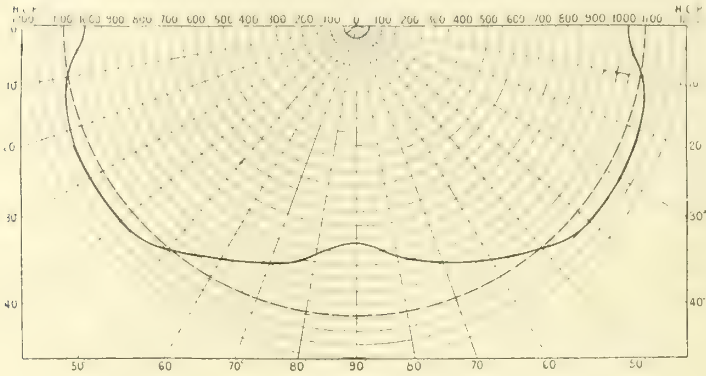


FIG. 5.

to an "ideal lamp" between Mr. Newbigging, the gas engineer to the Corporation of Manchester, and myself) is that all lamps are standardised, and when once fixed do not require any skilled labour or any individual adjustment. Any variation in quality or composition of gas which might affect the efficiency of the lamp can be corrected by adjusting a screw at the compressor, and this at once sets all the installation perfect. The large lamps are fitted with special Silica chimneys in place of the ordinary globes. The absorption of light by these chimneys is practically nil, and a most important consideration is that they do not break in case a jet of flame comes through the mantle and plays upon them.

Whilst the large lamps are intended for general illumination, the small ones are for special purposes, *e.g.*, the lighting of lathes, planing machines, drilling machines, &c., as well as for bench work. The 15 high-pressure lamps are fixed as shown on Fig. 4, 14ft. and 16ft. high, and the four 1,000 c.p. low-pressure lamps are fixed 35ft. high above the travelling cranes. Until recently the difficulty with respect to incandescent lighting for the purposes just enumerated was the inability to put the light just in the position required. This difficulty has now quite disappeared, and the arrangements shown in Figs. 1, 2, 3 can be adapted to all kinds of positions. The burner of the universal fitting, shown in Fig. 2, when adapted to a lathe, is fitted with a special reflector, which directs the light on the object to be examined, whilst completely shading the light from the workman's eye. The fitting allows the light to be turned to any position required.

Fig. 1 shows an arrangement whereby the light can be raised or lowered at will to suit varying conditions, whilst Fig. 3 shows an anti-vibrating arrangement for use in positions where the vibration is excessive. It is not usual to use globes with the small lamps, as the absorption of light is very great even with clear globes, and it was stated in a paper given lately by an electrical engineer that 25 per cent. of light was lost if globes and reflectors were not regularly cleaned. Wire guards are, however, used to prevent the mantle being damaged by contact with moving bodies.

The 1,000 c.p. high-pressure lamps give a distribution of light similar to that shown in Fig. 5. This diagram is constructed from tests made on a Grætzin (Thorp & Marsh type) lamp as in use on the Royal Exchange, Manchester. It will be at once seen that the curve of light distribution is almost an ideal one, as it gives practically an equal illumination for about 30° each side the vertical, the increasing candle-power of the lamp from the vertical to 30° compensating for the increased distance from the source of light to the floor, *e.g.*, the candle feet directly under the lamp at, say, 16ft. distance is 3·16ft. candles, whilst at 30° it is 2·92ft. candles. The figures are, of course, for surfaces normal to the light rays, and on the diagram, Fig. 6 showing illumination of the shops, we have taken them as such, seeing that the cosine law is not applicable in practice, the light falling upon the various objects at all angles. Fig. 6 shows a graphic method of indicating the candle-power of a light source at various angles and distances, and is due to my father, Mr. Thomas Thorp. We have found this most useful in making diagram Fig. 4. It will be seen that the normal light curve, the cosine curve, and the curve given by the Newbigging-Thorp lamp are given. Fig. 4 shows the general arrangement of high-pressure lamps and low-pressure lamps, and gives the illumination at the floor level. As previously mentioned, the foot candles are much in excess of that stipulated, but the gas consumption can be halved if 1½ft. candles only is desired. The section at A B shows the even illumination produced.

Maintenance.—The maintenance of a scheme as described is very low. It must again be borne in mind that the foot candles given are greatly in excess of that stipulated, for not only do the large lights show some 3ft. to 4ft. candles, but there is to be added the illumination produced by the 100 100 c.p. small lamps.

	Cost per hour.
Cost of gas for a total candle-power of 29,000 candles at 2s. per 1,000ft., plus allowance for 4 bye-passes to low-pressure lamps	14·6d
Large mantles—life average, 103 hours.........	1·50d.
Small mantles—life average, 300 hours	1·0d.
Silica chimneys on big lamps only	·1d.
Compressing from main shaft, ½ h.p.	·5d.
Attention, repairs, and cleaning	1·0d.
	18·7d.

Maintenance cost 1s. 6¾d. per working hour for 29,000 candles.

Suitability.—Under this head come: (1) Reliability. There can be no doubt as to the great advantages gas possesses on this point over its competitors, and it is unnecessary to do more than record the fact, although this should be the very first consideration in lighting an engineering works, seeing that a short temporary failure of light might have disastrous effects where there is moving machinery. In the

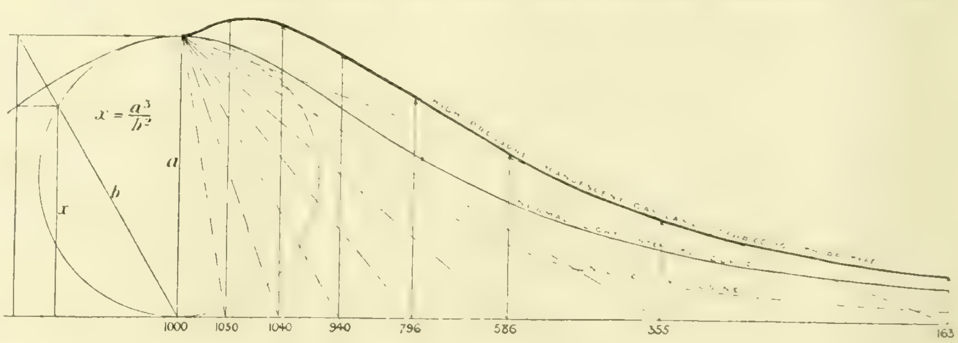


FIG. 6.

present gas scheme the only chance of general light failure would be a failure in the gas supply, and as this has only occurred at very few places out of thousands once in a hundred years, the danger is very small indeed. Failure of light due to accident to compressing plant (which is, by-the-way, only equal in possibility to that of general failure of electricity) is safeguarded by the 1,000 c.p. low-pressure lamps, which would give a good general illumination, and the 100 small lamps, which would give a fair illumination even with compressors stopped.

(2) The character and colour of incandescent gas lighting is acknowledged to be the nearest to that of daylight, not

only in steadiness but also with regard to the character of the spectrum.

(3) Steadiness. This is a most important advantage of gas. Contrast the beautiful, silent, steady, even illumination from a 1,000 c.p. gas lamp, with a noisy, flickering 1,000 c.p. arc, casting moving shadows, and giving an uneven, unpleasant light.

(4) The ease of manipulation and freedom from unpleasant shocks is of great advantage to users of gas. No special knowledge is required to keep the installation in perfect order, as is the case with competitive systems.

(5) The probability of improvement in efficiency in the case of gas has been shown in the earlier part of the paper, and this ought to weigh heavily in the favour of gas, as not only are the probabilities of increased efficiency very great but the cost of gas is steadily falling, whereas oil and similar commodities are increasing in cost.

(6) The adaptability of gas for various purposes has also been shown, for not only can the light be moved about as desired, but the sizes of the light units can be varied to suit all conditions.

Much more could be advanced in favour of gas as an illuminating agent, and much data produced to bear out the statements made, but I trust sufficient has been said to show that gas lighting is the ideal illumination for engineering works.

(To be continued.)

FEED-WATER HEATERS FOR LOCOMOTIVES.

We illustrate herewith an arrangement of feed - water heaters applied to a locomotive, the invention of Mr. F. H. Trevithick, Zeitoun, Cairo, Egypt. In this arrangement the smokebox is divided into two portions A B hinged together by a hinge of sufficient strength to carry the necessary weight. To the front or movable portion A is attached the smokebox heater D, carrying its own smokebox and the uptake or chimney E, the various parts being so positioned that the smokebox heater is placed comparatively low down in the smokebox, so as to ensure an efficient length of uptake, this feature being of importance particularly in connection with modern locomotives where the over-all length of chimney is limited by tunnels and bridges. With this arrangement the heater, when the smokebox is closed, is placed in the line of flow of the gases issuing from the fire tubes and consequently is in the most advantageous position for drawing these gases through them and the smokebox heater tubes. The connections between the smokebox heater and the exhaust steam heaters or between the steam cylinders and the boiler consists of two fixed pipes F G between which is a short movable pipe H divided into two compartments. The axis of rotation of the movable pipe H is in alignment with that of the smokebox hinge, and the upper and lower and fixed pipes F and G are provided with a packed gland and bush to form a ground swivelling joint to make water or steam-tight connections with the movable pipe H, and are connected respectively to the feed pipe or exhaust steam heaters and to the boiler clack box or to the boiler and the steam cylinder steam chests, according as to whether the smokebox heater is to be employed for feed-water heating or steam drying. The two compartments of the movable pipe H are connected respectively with the inlet and outlet of the smokebox heater, as clearly seen in Fig. 2. If the smokebox heater is to be employed for feed-water heating, a combination hinge of similar type may be arranged to provide the necessary connections between it and the feed pipe or exhaust heaters, the boiler water and steam spaces and the cylinders.

The smokebox heater D is provided with a spark arrester K and having the part W hinged so as to swing open, and it may also be arranged with its own smokebox R of reduced size, to which a supplementary door L is fitted, thus ensuring ready accessibility to the heater tubes and tube plates. The uptake E forms part of the heater smokebox, and it will be seen that by this arrangement an efficient length of chimney is secured, thereby ensuring an adequate draught for the exhaust steam up the smoke stack. The exhaust steam

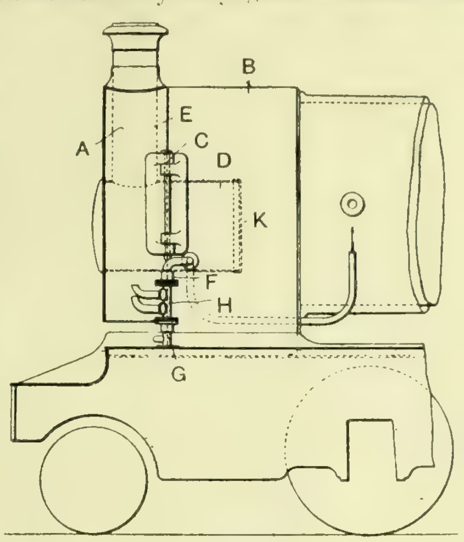


Fig. 1.

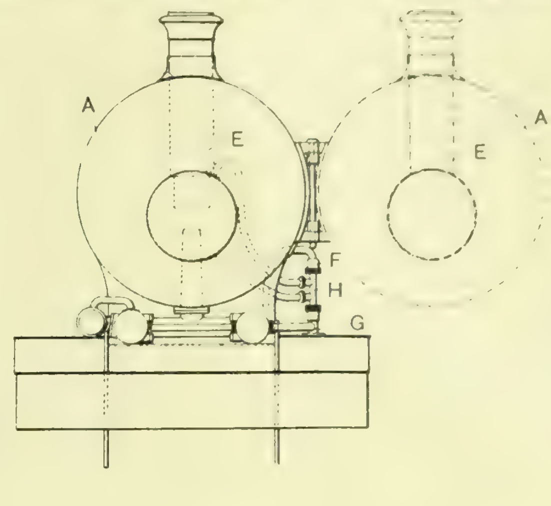


Fig. 2

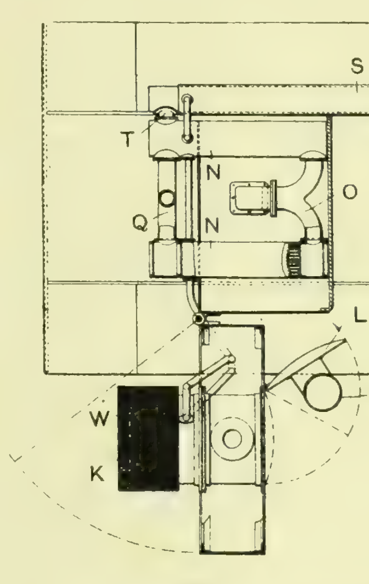


Fig. 3.

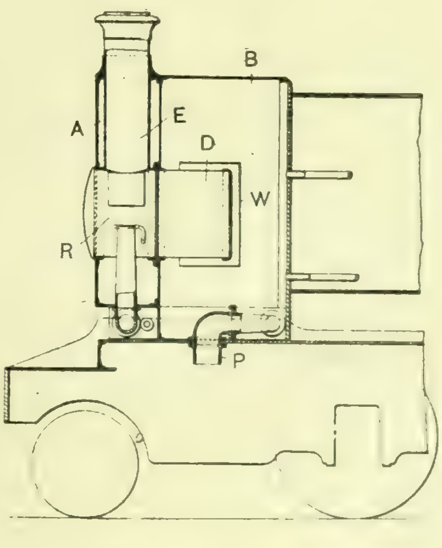


Fig. 4

Feed-water Heaters for Locomotives

heaters N are connected at one end by means of a Y connecting pipe O secured to the exhaust pipe P (Fig. 4) from the steam cylinders, while the other ends of the heaters are connected by a T-shaped blast pipe Q, the upper end of which is arranged to discharge into the heater smokebox R. The upper part of the blast pipe is carried by the movable portion of the smokebox, and any suitable form of jointing may be provided between the upper movable and lower fixed portion of the blast pipe arranged so that such joints may be quickly and easily made.

By means of this arrangement the whole of the exhaust steam passes from the cylinders through the feed-water heaters N N before issuing from the blast nozzle, and in order to prevent undue condensation of the exhaust steam in these heaters a supplementary heater S is provided, being fed with exhaust steam from an extension of the horizontal portion of the blast nozzle, as shown at T (Fig. 3), the supplementary

heater being provided with an outer casing U and suitable drain pipes from which the condensed exhaust steam may be allowed to drain.

LIQUID FUEL FOR POWER PRODUCTION.

THE second of the series of Cantor Lectures on liquid fuel delivered by Prof. Vivian B. Lewes at the Royal Society of Arts, dealt with the methods of utilising this fuel for the production of power. Differing but little in its ultimate composition, crude oil as it was won from the porous reservoir that formed the oil stratum was, he said, a mixture of the many hydrocarbons which constituted the three great groups of paraffins, ethylenes, and naphthenes. The crude oil was separated into the fractions needed by the markets of the world by a process of distillation in the refineries at the oilfields. It had a specific gravity which might vary between wide limits, and contained the whole range of the hydrocarbons of the groups which formed it.

With oils such as the Pennsylvanian, which consisted largely of paraffins, the natural gas which accompanied the oil and created the pressure that in a gushing well drove it from the bore consisted of the first member of the series, methane, while with it there was often 14 per cent. of the second member, ethane; in the oil itself were traces of the next two members in solution, while with the fifth member, pentane, the true oil began, and the higher members up to the 14th were liquids, getting, however, more heavy, more viscous, and less volatile the greater the number of atoms in the molecule, so that by the time the 15th member was reached pasty semi-solids like vaseline were obtained. The higher members of the group were true solids. Each step in the series was marked by an increase in specific gravity and boiling point, so that while pentane had a specific gravity of 0·64 and volatilised below the ordinary air temperature, by the time decane was reached the specific gravity had risen to 0·751 and the boiling point to 162° C. This rise in boiling point permitted the crude oil to be distilled at slowly rising temperatures, and, the distillates over given ranges having similar properties, to be fractionated into products fitted for the various purposes to which they were to be applied. The first distillates up to a temperature of 150° C. constituted what was technically known as "benzine," all of which might practically now be used as motor spirit; from 150° to 300° C. distilled over the lamp oil, used as an illuminant and generally called "kerosene," which now also was being used largely in some internal-combustion engines; while with oil obtained after these fractions had been distilled off was the portion used as liquid fuel for steam raising and furnace work, or for further distillation to produce lubricating and heavy oils, a residue of pitch or coke being left in the retort.

The problem to be solved in the use of liquid fuel was how best to utilise the largest proportion of the heat contained in it for conversion into power. The earliest practical attempts to do this consisted in burning the oil in porous beds or troughs, and in the Russian fields Nobel succeeded in getting very excellent results by fitting a gratework of troughs one above the other across the mouth of the furnace of a Lancashire boiler, and allowing crude oil to run in at the top and overflow from one trough to the other through the series. The crude oil containing considerable percentage of spirit burnt fiercely, and the flames were sucked by the draught in the chimney into the boiler space, evaporations as high as 13lbs. and 14lbs. of water per pound of fuel being obtained. Such a process could not, however, be employed for anything but stationary boilers, and the next phase was to arrange retorts and superheaters in the mouth of the boiler furnace, and there convert the oil into gas, the gas being driven forward into the furnace space. The gasifying of the oil being attended by many troubles, naturally the next idea that arose was to disintegrate the oil into the finest possible spray so as to aid combustion by getting the oil as near the gaseous condition as possible. There were three methods of atomising the oil, viz.: (1) Spraying it in as fine a state of division as possible by means of steam from a properly arranged injector; (2) using air under pressure instead of steam for this purpose, the air also serving to help the combustion; and (3) supplying the oil itself under pressure and driving it out through a specially arranged jet in such a way that it should be disintegrated.

From a very early date in the history of liquid fuel it became evident that its great future would be for marine purposes. When, however, attempts came to be made to introduce it, it was found that, although various injector burners answered admirably in tramp steamers, with Service vessels the furnace space was too small to allow the proper combustion of the amount of oil needed to give the required power, and that as a result dense black smoke was formed, which would at once have revealed the whereabouts of the vessel, and which also lowered the efficiency of the oil. Another trouble was that in order to provide the steam necessary for the atomisation of the oil extra boilers would have had to be provided, and at one time the idea of using liquid fuel was very nearly killed. Injection by means of compressed air also had the drawback that the jet of oil mist driven forward into the furnace space passed through it too rapidly for complete combustion, while the power used to give the pressure again necessitated the use of steam. Under these conditions direct-pressure burners began to be experimented with. The great advantage of ejecting the oil into the furnace space as a swirling cloud of mist instead of a direct-driven spray was that its passage through the furnace and combustion space was so retarded as to give sufficient time to complete its combustion.

For steam raising purposes petroleum might be taken as having an evaporative power, weight for weight, 50 per cent. higher than Welsh steam coal. On theoretical grounds it would be expected that the evaporative power would be about 15lbs. of water per pound of oil fuel. The evaporative power of a good oil fuel, as calculated from analysis, was 19·9lbs. of water from and at 212° Fah. As determined in the bomb the calorific value was 18,831 B.Th.U., and if this figure were divided by 966—the latent heat of steam in degrees Fah.—the evaporative power obtained was 19·5, so that it might be assumed that under theoretical conditions the evaporation per pound of oil would be about this quantity. Taking into account unavoidable heat losses, the evaporative duty of oil fuel should be 13·2lbs. in practice, instead of the calculated 19·5lbs.

Probably the phase of liquid fuel consumption which was attracting the largest amount of attention at present was the internal-combustion motor. When success first crowned the attempts to use liquid fuel for the purposes for which coal had always been employed, enthusiasts were to be found who declared that oil would replace coal entirely, oblivious of the fact that the world's output of crude oil was only a very small fraction of the coal production; while since the Diesel engine had proved its fitness for marine work by such installations as those on the "Vulcanus" and "Selandia," the same class of adherent was ready to avow that the Diesel engine would supplant steam for marine purposes, forgetting or not knowing that to do so the world's production would have to be doubled, and the whole of the supply devoted to this purpose. The choice of a prime mover was mainly a question of expense, and in spite of the Diesel engine consuming only one-third of the weight of fuel used by the best overtype superheated condensing steam plant, yet for a given power with coal at 18s. per ton and oil at 42s. per ton the annual cost of running the steam plant would be less than that of the Diesel engine, when all items of expense were taken into consideration. At the present moment, however, the price of fuel oil was far above 42s. per ton.

Prof. W. A. Bone had found that when a mixture of a combustible gas with air was forced under pressure through a porous diaphragm of asbestos and fireclay, if the mixture were ignited as it leaked through the porous mass, it could not explode, but burnt in the porous surface of the diaphragm and quickly raised it to a very high degree of incandescence, capable of yielding a very large proportion of its heat as radiant heat. The interest in this process with regard to liquid fuel was that it would work just as well with air carburetted with petrol vapour as with any other form of inflammable gas. The latest development of all was that if fuel oil were finely atomised with air in the right proportion, and then blown into the tubes containing the granular material in the Bonecourt boiler, providing that the granular mass had been first heated, complete combustion ensued and the same high efficiencies could be obtained as with gas burnt in the boiler.

INDUSTRIAL AND TRADE NOTES.

Shipbuilding in the United States.—According to the annual report of the Bureau of Navigation of the United States Department of Commerce and Labour, there was an increase of 135 in the number of vessels of all classes constructed in the United States during the year 1912, but a notable decrease in the total tonnage. During the year there were constructed in that country 1,727 vessels, with a total tonnage of 292,177, while figures for 1911 show that 1,592 vessels were constructed, totalling 309,640 tons. Steam vessels of steel construction showed a decrease in 1912 over 1911, while steam vessels of wooden construction showed an increase.

The Humphrey Pump.—At the new reservoir at Chingford the first of the five Humphrey explosion pumps, of 40 million gallons capacity, has been put to work. The performance has, we understand, exceeded expectations, both in regard to the amount of water raised—this being at the rate of fully 50,000,000 gallons a day—and the lack of vibration. The pump works on the 4-cycle principle, with the explosion in direct contact with the water, at a speed of about 10 cycles a minute. The pumps have been manufactured by Messrs. Siemens Bros. Dynamo Works, Ltd., to the designs of the inventor, Mr. H. A. Humphrey, of the Pump and Power Company.

Swan, Hunter, & Wigham Richardson.—At an extraordinary general meeting of Swan, Hunter, & Wigham Richardson, in Newcastle-on-Tyne on the 27th ult., the following resolution, which was passed at an extraordinary general meeting of the company on January 1st was submitted for confirmation in a special resolution: "That the capital of the company be increased to £2,000,000 by the creation of 300,000 new preference shares of £1 each, ranking as regards dividend, voting, and in all other respects *pari passu* with the existing preference shares in the company's capital, and by the creation of 200,000 ordinary shares of £1 each." Dr. G. B. Hunter, who presided, formally moved the resolution, which was seconded and carried unanimously.

Clyde Shipbuilding.—Only 11 vessels, aggregating 10,630 tons, were launched by Scottish shipbuilders during January. Of these, five of 9,755 tons were launched on the Clyde. The Clyde total is very small, but it is by no means the smallest on record for the month. On five former occasions the output for January was below 10,000 tons. It was lowest in 1908, when eight vessels of only 1,969 tons were launched. Last year the Clyde January output consisted of 39,526 tons, in 1911 it was 23,540 tons, in 1910 22,773 tons, and in 1909 21,430 tons. It is expected that before the year is very far gone the adverse balance on January will be more than wiped off. The shipyards are all very busy; there are quite a number of large vessels to be launched within the 12 months, as well as more than the average number of vessels of ordinary sizes and types, and the tonnage record for 1913 is very likely almost to equal if not to exceed the record figures of 1912.

Wages in the Iron Trade.—The ascertainment of the accountants for the Midland Iron and Steel Wages Board shows that for the months of November and December the output of manufactured iron was 40,146 tons, and the average net selling price £8. 1s. 6d. In accordance with the sliding scale arrangements the wages for puddling during the months of February and March, 1913, will be the same as those already prevailing. The ascertainment of the accountants, communicated to the Board of Conciliation and Arbitration for the manufactured iron and steel trade of the North of England, for the months of November and December, shows that the output was 9,212 tons, and average net selling price £6. 6s. 6d. The wages for February and March will be the same as prevailed in the preceding two months. The following intimation has been made to Messrs. James C. Bishop and James Gavin, joint secretaries of the Scottish Manufactured Iron Trade Conciliation and Arbitration Board, by Mr. John M. MacLeod, C.A., Glasgow: "In terms of the remit I have examined the employers' books for November and December, 1912, and I certify the average net selling price at works brought out is £7. 6s. 8·71d. per ton. This means no change in the wages of the workmen."

Arbitration in the Iron Trade.—The annual meeting of the Board of Conciliation and Arbitration for the Manufactured Iron and Steel Trade of the North of England was held at Newcastle on the 27th ult. The president, Mr. W. Thackray, Monkwearmouth, in moving the adoption of the report, said that in the iron and steel trade of the North there was plenty of work for all who wanted it. If labour troubles in other branches of trade did not bother them and legislation were to leave them severely alone they might congratulate themselves on the prospects of the present year. They could congratulate themselves on their mode of settlement by arbitration calm discussion, and reason. If that mode prevailed instead of the brute force of strikes, it would be better for every trade. As to the question of enforcing agreements, they did not want the help of compulsory arbitration, and his own evidence before the Commission in London was that they could do very well by themselves if let alone. Mr. W. C. Griffiths seconded, and the report was adopted. The re-election of officers took place as follow: Sir W. H. Stephenson, referee; Mr. W. Thackray, president; Mr. W. C. Griffiths, vice-president; Messrs. Winpenny and Cox, secretaries; Messrs. H. C. McBeath and T. B. Pugh, auditors, and Messrs. R. W. Davies and John Ellison, treasurers.

Benzol as Motor Fuel.—The Petrol Committee of the Royal Automobile Club, in their second report just issued, express the view that no further useful action can be taken at the moment in regard to the supply or distribution of petrol that would tend to reduce the cost of the spirit to consumers. They point out that the demand for petrol is almost greater than the apparent existing supply, and this demand is rapidly increasing in all countries. The Royal Automobile Club have intimated their willingness to conduct tests with liquid, solid, and gaseous fuels, for both pleasure and commercial motor vehicles, and to consider the desirability of holding a public competition of vehicles propelled by fuels other than exclusively petrol. Various suggestions have been submitted to the committee for alternative fuels, and the most suitable under present engine conditions, and most likely to be possible of production to a competitive extent, appears, the committee considers, to be benzol. The Automobile Association and Motor Union and the Society of Motor Manufacturers and Traders have formed a joint committee, to which they have between them contributed £1,000 to defray the necessary expenses in order specially to investigate the possibilities of benzol as a fuel. The result of the labours of this joint committee will be embodied in the final report of the Petrol Committee.

Compulsory Arbitration in the Coal Trade.—Mr. Joseph Shaw, K.C., chairman of the Powell Duffryn Steam Coal Company, and Mr. William Gascoyne Dalziel, secretary of the Monmouthshire and South Wales Coalowners' Association, were the principal witnesses at the sitting of the Industrial Council held in London on the 29th ult. Mr. Shaw said his company was the owner of collieries having an output of about 4,000,000 tons annually. So far as the Monmouthshire and South Wales coalfield was concerned he was satisfied that the machinery in operation for dealing with the general rate of wages and disputes was the most suitable, and he should deprecate any legislation in the nature of compulsory arbitration. Where agreements had been made between representative bodies of employers and workmen he thought they should be enforced by rendering the funds of the association liable where the breach had been brought about by the association or its officials, or the workmen were financially supported by the association where a strike was illegal. Unless this was done he was satisfied that contracts would be broken whenever it suited the workmen's representatives to do so. He was aware that this would mean the repeal of the Trades Disputes Act, but he saw no alternative, having carefully considered the matter. Mr. W. G. Dalziel gave evidence as to the agreements, &c., affecting the South Wales coalfield, and said the principle of collective bargaining between the colliery owners and the workmen was recognised as far back as 1875, and had been maintained ever since. If an arbitrator were brought in from outside with plenary powers they would never have conciliation.

Oil Engines for Marine Propulsion.—At the annual dinner of the Scottish staff of Lloyd's Register, held at Glasgow on Saturday last, Mr. C. E. Brightman stated that during the year 1912 Lloyd's Register classed the record total of 1,403,000 tons, while the total classed during the existence of the society exceeded 42,500,000 tons. At the close of 1912 88 per cent. of the tonnage under construction in the United Kingdom for British classification was for Lloyd's. Practically the whole of the immense tonnage of oil-carrying vessels now under construction and of vessels on the Isherwood system of longitudinal framing was for their classification, while there were also being built under their special survey vessels representing nearly 100,000 tons of shipping for internal-combustion engines. The development of this special type of engine was being followed closely by their committee. Mr. Milton, their chief engineer surveyor, had visited all the principal works where such engines were made in the United Kingdom and on the Continent, and had discussed exhaustively with the various makers all the details of their construction. Wherever possible full details had been obtained of results in working; personal inspection had been made by their surveyors on every possible opportunity, and advantage had been taken of the information obtained to guide them in deal

ing with new cases. There were considerable differences of opinion on many points, as to which no dogmatic conclusions could be formulated until time had supplied them with the results of experience. Definite requirements were being made, however, with respect to details of construction and equipment for which sufficient data were available, and careful watch was kept on the progress of the engine for the purpose of making these requirements as complete as possible.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL. 1911.

Production of motor spirit. De Fazi. 25177.
Arrangements for promoting circulation in steam boilers. Circulators, Ltd., Ross, and Schofield. 25320.
Variable speed gears. Dron & Lawson, Ltd., and Fulton. 25516.
Hoisting and lowering apparatus. Tabulo. 28215.

1912.

Apparatus for injecting fuel into internal combustion engines. Rundlof. 690.
Distributing valve for compound steam engines. Bloxham. 805.
Tool or device for turning and screw threading metal. Land. 887.
Controlling mechanisms for preventing overwinding in winding gears. Black & Thornewill. 911.
Variable speed hydraulic transmission gearing. Soc. Anon. des Etablissements Delaunay Belleville. 1063.
Self opening dies for screwing machines. Hartwell. 1133.
Tin and terne plate machines. Lewis & Lewis. 1185.
Gas producers. Lymn & Rambusch. 1232.
Rotary fans and blowers. Bretherick. 1381.
Motor vehicles. Alexander. 1418.
Gravity feed apparatus for returning water of condensation to the boiler. Leib. 1448.
Hammer rock drills and percussive hammers. Daw & Daw. 1461.
Variable speed gears for motor vehicles. Dean. 1513.
Feed water heaters and purifiers. Brougham. 1552.
Means for propelling ships. Metcalfe. 1595.
Apparatus for pumping corrosive liquids. Lennox. 1610.
Speed-varying means. Fitton. 1637.
Swivel vices. Peters & Kassell. 2304.
Furnace grates for steam generators. Neil & Rutherford. 2489.
Metallurgical furnaces. Cornthwaite. 2709.
Thermostatic valves and steam traps. Sawyer. 2851.
Starting gear for internal combustion engines. Fuller. 2963.
Clutches. Bowley. 3118.
Water cooled internal combustion engines. Owers. 3563.
Apparatus for separating grease and other impurities from steam. Burton, and Garner, Telford, & Hardman, Ltd. 3905.
Carburetters for internal combustion engines. Charles H. Pugh, Ltd., and Bull. 4081.
Furnaces for steam generators. Anderson, Meikle, & Fulton. 4445.
Variable-speed gear. Manly. 4888.
Adjustable template. Baines & Portass. 4961.
Screw type fans. Eatwell. 5378.
Self contained and automatic machine or engine for use where stationary power is required. Davis & Hadley. 5618.
Manufacture of metal wheels for road vehicles. Clarkson and Morison. 5784.
Steam engine for motor road vehicles. Pearson, Cox, and Pearson & Cox, Ltd. 6064.
Internal combustion engines. Davidson. 6125.
Wire ropes. Bullivant & Selby. 7160.
Nut locks. Stott. 8026.
Cylinder piston rings. Gibb. 9104.
Apparatus for lubricating the bearings of long driving shafts in tube pumps. Neufeldt & Zurovec. 9273.
Two stroke cycle continuous combustion internal combustion engines for ships. Kilburn. 9525.
Nut locks. Orbin & Mossburg. 9591.
Bronze alloy. Springorum. 9953.
Foundry flasks. Smith. 10216.
Rotary engines and compressors. Lake. 10809.
Universal joints. Prescott. 11335.
Linkages for transmitting rotary motion. Sturgeon. 11410.
Motor cars. Scholer. 11934.
Connecting rods for internal combustion engines. Patrick. 12118.
Screw propellers. Boutwell. 12170.
Drill chucks. Mackenzie. 12566.
Devices for measuring or regulating the quantity of liquid forced by a pump. Keller. 12990.
Power driven vehicles. Dunlavy. 14626.
Reciprocating conveyers. Norton. 14952.
Internal combustion turbine. Woodford. 15214.
Speed reducing gears. Wallwork & Shillito. 16216.
Gas generators. Marot. 17405.
Variable speed gearing. Guillot & Basset. 18717.
Compressor or air pump. Burghard. 19421.
Rotary apparatus for exhausting or compressing air or other elastic fluid by means of an auxiliary liquid. G. & J. Weir, Ltd., and Petermoller. 19872.
Means for lubricating vertical shafts and their bearings. Martin. 20548.
Propelling mechanism for aeroplanes and air ships. Viëtor. 20751.
Railway rail joints. Hammock. 21143.
Pulley blocks. Dornte. 21341.
Gear wheels. British Thomson Houston Company. 22666.
Bearings. Chinnick. 22863.
Reducing valves for high pressures. David Auld & Sons, Ltd., Auld, and Graham. 23242.
Metal shaping machines. Sonnenthal & Lord. 23247.
Hydraulic jet elevators. Heinecke. 24033.
Testing instrument for flue and furnace gases. Schmid. 25046.
Change speed gear. Marcellot. 26645.
Process for the production of oils or spirits adapted for use in internal combustion engines. De Fazi. 27679.
Rotary pumps. Universal Rundlaufmaschine Ges. 28361.
Railway couplings. Babington. 29058.

ELECTRICAL, 1912.

Electric storage batteries. Niblett. 819.
Vapour electric lamps. Bousson & Guesnier. 991.
Holders for electric lamps. Müller. 1166.
Transmitting switch apparatus for the control of electric motors. Vickers, Ltd., and Creffield. 1280.
Electric supply systems having variable speed generators. British Thomson Houston Company, and Garton. 1681.
Control of alternating current electric motors. Rosenberg. 1979.
Methods of and machines for electric welding. British Thomson Houston Company. 2343.
Rotating interrupters for magneto ignition apparatus. Diehl. 2472.
Renewable electric incandescent lamps. Bailey & Plews. 3906.
Electric block signalling systems. Siemens Bros. & Co. 5559.
Electrical switches. Price. 5562.
Electrically operated valve controlling devices. Keith & Keith. 6517.
Galvanometers. Clark & May. 9094.
Incandescent electric lamps. Lusted. 9983.
Wireless telegraphy apparatus. Peake. 10501.
Machines for forming filaments for electric lamps. British Thomson Houston Company. 11252.
Electro deposition of metals. Round & Fisher. 15192.
Electric boilers. Bally. 16042.
Electric furnaces. Bocuze. 21290.
Electric switches. Lundberg, Lundberg, & Lundberg. 21913.
Automatic controlling device for electric cut outs. De Thierry. 22251.

METAL QUOTATIONS.

TUESDAY, FEBRUARY 4TH.

Aluminium ingot	93/- per cwt.
„ wire, according to sizes, &c. ......from	112/- „
„ sheets „ „ ...... „	120/- „
Antimony ......£37 -/- to	£40/-/- per ton.
Brass, rolled	$9\frac{1}{2}$d. per lb.
„ tubes (brazed)	$10\frac{1}{2}$d.
„ „ (solid drawn)	$9\frac{1}{8}$d.
„ „ wire	8[illegible]d.
Copper, Standard	£68 7/6 per ton.
Iron, Cleveland	$65/1\frac{1}{2}$ „
„ Scotch	$71/1\frac{1}{2}$ „
Lead, English	£17/2/6 „
„ Foreign (soft)	£16/15/- „
Mica (in original cases), small	6d. to 3/- per lb
„ „ „ medium	3/6 to 6/- „
„ „ „ large	7/6 to 11/- „
Quicksilver	£7/15/- per bottle
Silver	$28\frac{13}{16}$d. per oz.
Spelter	£26/2/6 per ton.
Tin, block	£224/15/- „
Tin plates	15/- „
Zinc sheets (Silesian)	£29/7/6 „
„ (Stettin; Vieille Montagne)	£29/17/6 „

The Mechanical Engineer.

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WILLIAM H. FOWLER
Wh. Sc., M.Inst.C.E.

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Canadian Legislation and Industrial Disputes.

AT the time of the coal strike and railway strike a good deal was heard about the labour legislation of Canada and its beneficent effect in preventing strikes and lockouts, and last autumn Sir George Askwith, who has established a reputation as a happy conciliator in trade disputes, was deputed, in conjunction with Mr. Isaac Mitchell, of the Board of Trade Labour Department, to make a tour of the Dominion to investigate the working of their enactments, and report as to the desirability of instituting legislation with a similar object here. Although the report disposes of some of the exaggerated ideas that were prevalent as to the potency of legislation to dispose of labour troubles, it is of interest, and deserving of study.

The Lemieux Act, named after the Canadian Minister of Labour during whose term of office it was passed in 1907, was the outcome of the Railway Labour Disputes Act, passed some four years previously, and under which the Dominion Government had the power to refer any railway dispute to a Committee of Conciliation, and failing that to a Board of Arbitrators, who could recommend terms of settlement but could not enforce them. Under its operations, railway strikes became less frequent, and as there appears a disposition both on the part of railway companies and railway unions to appeal to and accept the decisions of these tribunals, the Lemieux Act was adopted without much opposition. Its operations carried Government action a step further, and ensured the recognition of public interests in other industries, such as mining and shipping, on whose continuity national well-being so vitally depends. The Act, however, which came into force on October 22nd, 1907, is not, as some imagine, one for compulsory arbitration. It only enacts that in any dispute in the industries mentioned, *i.e.*, mining, agency of transportation, or communication, or public service

utility, the questions shall be submitted to a Board, with a view to arriving at a settlement before a strike or lockout can be begun, and that at least thirty days' notice shall be given by either employers or workmen of any intended change in working hours or conditions. Pending proceedings before a Board in case of dispute, a strike, or a lockout in these services is illegal, the penalty for infringement being from $100 to $1,000 per day for an employer, and from $10 to $50 per day for a workman, while inciting or encouraging by either party are deemed to be offences, and similarly punishable.

It will be seen the Act only endeavours to postpone a stoppage of work in certain special industries for a brief period and for a specific purpose. It does not destroy the rights of employers or workpeople to terminate contracts, or interfere with details of administration of business or organisation of trade unions. It proceeds simply on the assumption that differences may be adjusted by discussion and negotiation, and secures that before a stoppage does take place the possibilities of amicable settlement shall at least have been tried. Failing this end both sides are then at liberty to take such action as they may think fit. The Act, it will be seen, does not differ materially from any other method of voluntary conciliation that may be resorted to. Its real value lies in the insistence that conciliatory efforts shall at least have a chance, and by their publicity help to form a wider opinion that in the final resort must decide any big dispute concerned with a vital national utility. In trades outside the narrow circle specified it is difficult for outsiders to form a sound opinion as to the merits of a particular dispute, and in the absence of its influence the combatants must perforce fight out their quarrels between themselves.

The reception of the Lemieux Act is not by any means so universally friendly as some writers here have sought to convey. Labour generally is suspicious of its powers and operations, and though the Railway Union officials have reversed the attitude they first assumed towards it and are now warm supporters, the Mine Workers' Union, on the other hand, is frankly hostile, and its opposition is reflected widely in the fact that the Canadian Trades Union Congress passes an annual resolution demanding its repeal, on the ground that it deprives workmen of the right to strike at the most opportune moment, and on the other hand enables employers to prepare for a stoppage. It is also contended the Boards are of a partisan character, their decisions are unfair, and that employers refuse to accept recommendations made by them. Much of this sounds familiar to those acquainted with the history of recent British labour troubles, and its echoes from Canada do not inspire hopes that relief will be found by the adoption of similar legislation here, at all events not in trades outside transportation and communication services. Disputes in other trades in Canada appear to be settled pretty much by similar methods to our own, and any attempt to increase legislative interference there, would, if we judge rightly from the report, probably aggravate rather than diminish them. It is a somewhat regretful conclusion to arrive at, but reading between the lines of Sir G. Askwith's report it is the one to which even he is led, for he says, "Where the Act is frankly accepted it works extremely well, but where by the imposition of penalties efforts have been made to enforce the Act the results have not been satisfactory."

Of course, this is what we should expect in any case. With a disposition to meet and discuss differences, conciliation flows without difficulty. But when attempts are made to bind judgments with legal penalties trouble occurs. This has been the bane of the majority of labour differences during recent years, and the absence of all sense of responsibility and utter disregard of the bonds attaching to solemn engagements and contracts which has been displayed by large sections of workers has been the despair of honourable men. To the credit of trade union officials, it must be admitted that many of them have strongly denounced such breaches of faith and discipline. But the unfortunate part of the business has been that rational leaders have, especially in the lower and less educated classes of labour, been dethroned in favour of agitators more bent on personal notoriety than the social improvement of their fellows. It is to be feared, too, that latter-day legislation in respect to picketing, immunity from actions for tort, or responsibility for agents, has tended to foster a spirit of lawlessness, and until this gives way to a higher regard for the sanctity of engagements and personal liberty there is little prospect, except in few instances, of settling disputes on the lines of the Lemieux Act. In the cases where it does apply, the public will insist finally on taking a hand in the game and bringing it to an end quickly, as it did in the railway strike. But to the general run of trade disputes public opinion is apathetic or indifferent, and in face of this attitude and the difficulty of securing decent observance of labour contracts or the infliction of penalties for their breach, employers may well ask why put on further fetters? Until workmen's unions are prepared to forego the right to strike and to submit to penalties for indulging in it without notice and in violation of agreements, in other words, to carry the legal obligations which attach to all other organisations of men, so long will employers claim the right to lock out. Both resorts are brutal, but, in our opinion, Parliament is largely responsible for many of the indulgences in those we have had during recent years by the immunity it has accorded to trade unions through the Trades Disputes Act, and there is little chance of strikes and lockouts being ended until this piece of legislation is considerably amended.

MODERN TESTING METHODS.

At a meeting of the Staffordshire Iron and Steel Institute, held at Dudley, on Saturday last, a paper on testing apparatus as applied to modern works practice was read by Mr. George Hailstone, who said that in designing all types and classes of engineering work questions as to the strength and rigidity of the materials were involved. It was, however, of late years that the problem of using materials to the greatest advantage in securing the highest strength had thrust itself ahead of other considerations in the mind of the designer. In modern engineering work, whether it be the construction of a bridge, a high-speed steam engine, or a motor-cycle engine, whatever objects were in view the designer always had to consider what straining actions the structure or engine would be subjected to, what was the best and safest materials to be used in the various parts, and the least amount of the different materials necessary to resist those straining actions. The simplest method of ascertaining the safety of a bridge or engine was to apply to it a testing load greater than the maximum load to which it was likely to be subjected. An extreme testing load might damage a boiler or bridge without any possibility of the injury being detected at the time. Such tests of completed structures were useful as affording a final guarantee of security, but they did not supply specific information as to the margin of safety that existed. For the largest number of constructions no testing could be applied except the ordinary working load. It was here that the mechanical testing of the materials was of great assistance to the engineer in the selection of the material to be used in any particular machine or structure. There were two distinct objects in view in testing materials mechanically. The one was the scientific and the other the commercial. When testing to a scientific end the experimenter aimed at the determination of the physical constituents of the material and at verifying the assumptions on which theoretical calculations proceeded. When the experimenter endeavoured to ascertain whether samples of a material complied with certain standards of quality, or which of two samples of material was the better, this was known as commercial testing. Mr. Hailstone subsequently explained the most recent methods of testing materials, and also described types of testing machines.

FEED MECHANISM FOR SHAPING MACHINES.

The feed mechanism usually employed on shaping machines includes a ratchet wheel engaged by a pawl which is actuated by a link connected to a crank of variable throw, by adjusting which the travel of the pawl and the amount of feed can be varied, whilst by reversing the pawl the feed can be reversed. Usually, with machines having feed mechanism of this type, the whole machine has to be stopped to effect an adjustment of the throw of the crank pin for alteration of feed, or to enable the setting to be changed when the table is required to work in the reverse direction. It is preferable to effect the feed during return of the tool, so that the crank requires a different setting for reversal of the pawl in cases where the feed is effected in both directions. The arrangement illustrated herewith, the invention of Mr. H. M. Sonnenthal, of the Selson Engineering Company, Ltd., 85, Queen Victoria Street, London, E.C., and Mr. A. Lord, has been designed with a view to dispense with the necessity for stopping the complete machine during adjustment, or change of setting of the crank. This is effected by providing simple disengaging means between the crank and its shaft or the shaft and its driving member, and is so constructed that it can engage in two diametrically opposite positions so that the setting of the crank may be altered diametrically with regard to its driving gear.

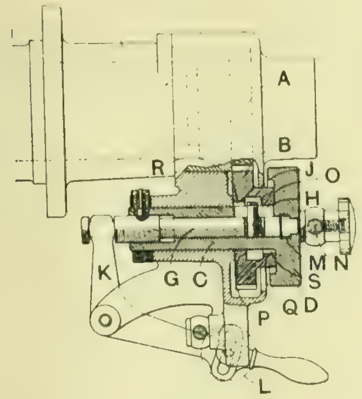


Fig. 1.

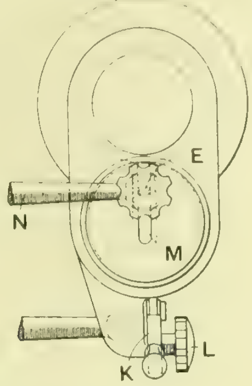


Fig. 2.

Feed Mechanism for Shaping Machines.

Fig. 1 is a part sectional view of part of a metal shaping machine fitted with the arrangement, Fig. 2 is an end view of the same, whilst Figs. 3 and 4 are diagrams showing the alterations necessary to effect feed in opposite directions. The driving wheel A, connected with the bull wheel which actuates the tool carrying ram, drives a gear wheel B of the same diameter which is mounted loosely on a sleeve C terminating in a crank disc D. This crank disc is slotted radially as shown at M and carries in the slot a crank pin E which can be adjusted from the centre of the disc outwards. The pin E is connected by a link N to the feed pawl F, and it will be understood that by adjustment of the crank pin in the radial slot M the travel of the pawl is varied in the well-known manner. The sleeve C is slotted at O close to the gear wheel B and passing through the sleeve is a rod G carrying a cross pin H which projects on one side through the slotted sleeve. The gear wheel B is provided with a groove J more or less centrally arranged, leaving rings P and Q on each side which may take a bearing on the sleeve C. These rings are notched at R and S to receive the end of the cross pin H. It will be clear that when the rod G is moved in the correct manner it engages the cross pin with one of the notches R and S on the wheel, the sleeve and wheel being thus clutched together, and the crank disc is driven from the driving gear wheel A and the feed pawl operated. To disengage the crank disc the rod G is moved to slide the cross pin into the groove J in the gear wheel, when the machine will continue to run, but the crank disc will remain stationary, permitting adjustment of the crank pin. The rod G is actuated through a bell crank lever K provided with locking means, and if desired a spring is provided tending to hold the parts in the engaged position. To disengage the pin H from the wheel the bell-crank lever is operated, and the locking screw then used to hold the lever in the disengaged position. To re-engage, the locking screw L is released, when the cross pin can be re-engaged.

The mechanism so far described provides for easy means for disengaging the crank disc D from its driving mechanism by movement of the lever K. It will be clear that this can be effected without stopping the machine and that when effected the throw of the crank pin E can be adjusted radially. To reverse the machine it is necessary either that the crank pin should take up a position diametrically opposite to that which it occupied previously, or, what is the equivalent, that the mechanism should have moved half a revolution with the crank disc remaining stationary in the same position, at the end of which period it is again clutched to its driving mechanism. Fig. 3 shows for example the position of the crank pin and the driving pawl. The crank pin is on the lowest side of the axis of the crank disc and the pawl F is so set that the feed takes place when the link N moves in the direction of the arrow. It will be seen that the feed occurs when the crank pin E is moving through the lower semicircle of its travel. To feed when the work is moving in the opposite direction the pawl F has to be reversed and the crank pin E or disc has to be moved through half a revolution, or, what effects the same results, the crank pin must remain in its old position and the driving mechanism between the ram and the crank disc must be moved through half a revolution. In the case shown in Fig. 4 feed occurs when the link is moving in the direction of the arrow.

The arrangement also provides means for clutching the disc D to the driving mechanism in two diametrically opposite positions. Figs. 3 and 4 show the crank pin on opposite sides of the axis of the crank disc, the pin and disc having previously been rotated through half a revolution. This is not what is actually effected in the machine as the crank pin always remains on the same side of the axis of the crank disc. The diagrams referred to illustrate the requirements, which are fulfilled by the arrangement. For this purpose two notches are provided diametrically opposite to one another and when it is desired to reverse the feed the cross pin is, by means of the lever K, moved out of its previous position in the one notch and into the other notch so that feed takes place during the opposite half revolution of the gear wheel B. The pawl must now be reversed, as is usual. Any suitable indicator means may be provided to enable the operator to ascertain at a glance whether the feed is taking place during the cutting or return strokes of the tool. It will be seen that for reversal of the feed it is not necessary to stop the machine and reset the crank. The crank always lies on the same side of the centre of the crank disc, but its relation to the bull wheel and its driving gear wheel is changed during reversal. The reversing is therefore effected automatically directly the lever is depressed and released.

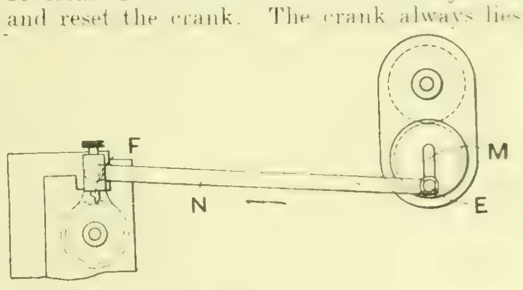


Fig. 3.

Fig. 4.

Feed Mechanism for Shaping Machines.

Automatic Telephones for New Zealand.—The New Zealand Government have decided to install automatic telephones in Wellington and Auckland. The replacement will take place gradually, and a thousand instruments have been ordered from America as a start.

THE PRODUCTION AND RESOURCES OF LIQUID FUEL.

In his third and concluding Cantor lecture on "Liquid Fuel," delivered at the Society of Arts, Prof. Vivian B. Lewes dealt with the production and future supply of this fuel. According to the lecturer, the total weight of crude oil produced in 1912 was between 40 and 50 million tons, and of that total 1½ million tons, the bulk of which, viz., 980,000 tons, came from the United States, was imported into this country. The use of fuel oil was, he said, advancing more rapidly in America than anywhere else, and for that reason it was useless to rely on that country continuing cheap supplies for long. The same thing was also true of the Russian fields. In India, the West Indies, Canada, and many other places there was the possibility of obtaining oil by proper development. It was evident, however, that even if the supply of oil continued to increase in practically the ratio shown by the last ten years, the demand must soon get ahead of the supply, and that, owing to our position, it would be only by very careful handling of the commercial side of the question that we should be able to command a sufficiently large share of it for our requirements. The whole of the available evidence pointed clearly to the supply of oil from existing fields being less in quantity.

The keeping up of the world's supply must depend on the opening up of new oilfields, and the question was, would the new fields show anything like the producing power of the old ones, and did indications justify the supposition that many such areas existed? Although huge and unsuspected oil areas, of which no signs had been found at the present time, might exist, it was by no means certain that as the present fields became depleted new ones would be opened up with sufficient production to keep up the supply. Dr. Engler had put the period over which oil would be available for the purposes for which it was now used at 100 years, but the lecturer personally doubted if in 50 years' time it would be obtainable at a price that would enable it to be used commercially. The last century would always be distinguished in history as the coal fuel era, while the use of oil would mark the twentieth century, or at any rate the first half of it. After that who could say? Probably there would be a "residues" era in which the dregs of the coal and oil supply would be utilised. After that would come the settling down to the only forms of fuel that would give rapid regeneration of energy, and wood and alcohol would regulate the power amongst nations to those that had the greatest growing area at command.

Benzine or petrol constituted an average of 20 per cent. of the world's supply of crude oil. A quarter of a century ago it was almost a waste product, its chief use being as a grease solvent. Then came the perfecting of the petrol motor by Daimler, the introduction of the motor-car, and the rapidly rising demand for petrol, which last year in this country alone necessitated a supply of 80 million gallons. The increase in consumption was not confined to England; it had been as great or greater in every civilised country of the world, with the result that the once despised light fraction of the crude oil had become the most paying product. In order to supply the demand the stocks of crude oil held in the fields had been depleted and distilled, and the fraction for this purpose had been increased at the expense of the kerosene fraction, by distilling up to a higher temperature, and so had increased in gravity, the result being that, while the specific gravity of motor spirit ten years ago was about ·680, there was now but little under ·700, and plenty of ·720 and even higher. This meant that if the demand went on increasing as it had done of late, the world's supply would be utterly inadequate, and further rise in price was inevitable.

The way to keep the price of petrol within reasonable bounds was to develop steadily all processes that would increase the supply, not only of petrol, but of petrol substitutes, always bearing in mind that with the present consumption ever increasing, petrol itself could not supply the market for even another ten years, and would probably be a rarity as a motor fuel long before the end of the century. What processes were at hand by which the supply of petrol could be increased from the higher grades of oil which remained after the light fractions had been distilled? In the refineries at the oilfields it had long been known that by prolonging the period of heating the fractions of light oil were increased, and the heads or tops of the stills were left unlagged so that the distilling oil might condense and drip back into the retort to undergo a further period of heating. This process of decomposing oil of heavy specific gravity and high boiling point into mixed hydrocarbons of low gravity and boiling point was known as "cracking," and with the demand for light hydrocarbons such methods deserved all the attention that could be given them. At works on the lower Thames a grade of oil, "Solar Oil," which distilled over after the kerosene had been separated from American oil, and which was very cheap and largely used for enriching water gas for admixture with coal gas, was sprayed with water into long iron retorts filled with iron turnings kept at a temperature of 600° C. The water and oil being volatilised were drawn by the suck of an exhauster through the heated material, where the oil was cracked and the vapours passed through an atmospheric condenser, where any heavy or unchanged oil condensed and was returned to the retort to undergo further cracking. The light vapours passing forward were condensed in water coolers and the lightest spirit finally extracted by oil scrubbers, the permanent gases going to a holder and forming the fuel that heated the plant. The condensed and scrubbed out products were then passed through a continuous steam still, and the spirit distilled from them, the residual oil from this still, together with the condensed oil from the atmospheric condenser, being mixed with fresh oil and going back to the cracking retort or converter. By this method 100 galls. of Solar oil yielded 65 galls. of liquid residuals, 39 galls. being petrol and 13 galls. solvent spirit.

Another way in which an increase in the petrol supply could be obtained, and which was already being largely used, was to carry on the distillation of the original fraction for light oil beyond the 150°. C., which in the past had been the limit, so as to increase the bulk of the petrol at the expense of the kerosene fraction. This could perfectly well be done up to a certain point, and that it was being done was shown by the gradually increasing gravity of the petrol placed upon the market. Great care, however, had to be taken not to exceed certain limits, as otherwise the flexibility of the motor was impaired and troubles arose in starting from cold. A small addition to the petrol supply could be obtained from the distillation of Scotch shale, an industry located in the Lothians, which yielded about 600,000 galls. of excellent motor spirit per annum. This was a very small fraction of the 80,000,000 galls. used last year, but no doubt the amount could be increased considerably with increase in the industry and also by employing cracking processes to augment the spirit fraction at the expense of the lighting oil.

Benzol, or, as it was sometimes termed "benzene," which must in no way be confused with "benzine," used as the name for the light fractions of mineral oil, was a product of the destructive distillation of coal, but it was only in large works that it had been extracted from the tar in which it was found, while considerable demand existed for it as the base from which all the coal tar colours were derived. Some 32 million tons of coal were carbonised annually for coal gas and metallurgical coke, and if proper arrangements for recovering the whole of the benzol from this amount were made, a very considerable supply could be assured. Under existing conditions less than half the coal was coked in recovery ovens, and most of the benzol so recovered went abroad. If methods of carbonisation were adopted which favoured the production of light hydrocarbons in the tar, and if then the tax on petrol were removed and an export tax to recover the amount were put upon benzol, a very important addition to the petrol supply could be ensured.

There need be no fear as to the future of the motor or the eventual price of petrol. In 1907, or even earlier, the lecturer pointed out that alcohol formed a better fuel, far safer and less objectionable in its products, than petrol, and that, moreover, it was the only fuel which would be available in the future, as by its formation from vegetation it was possible to regenerate rapidly the sun's energy, which was the only source of power. Inasmuch as during the last year many others had joined in the same cry, it was probable that in the near future advances might be made in the perfecting of alcohol motors, which, owing to the high compression possible, would give as great a power as petrol, although the heat

energy contained per unit of alcohol was only about one half that of the petrol.

The proportion of the crude oil distilling between 150° and 300° C. was the fraction called kerosene, and was the source of the illuminating oils burnt in lamps and used in many forms of internal-combustion engines not fitted for the heavier grades of oil. The efforts to increase the yield of petrol were now infringing upon this fraction, and in the future it was not at all improbable that it would gradually become absorbed by the demand for petrol, on the one hand, and fuel oil, on the other, as it lent itself to both purposes. With coal gas, electricity, acetylene, and air-gas to fill the field of illumination its loss would not be felt very keenly; moreover, as it constituted at least a quarter of the crude oil, its division between the two remaining fractions would increase materially the world's supply of them.

Fuel oil, the fraction above 300° C. was not only important as being the form of oil best fitted for naval needs, but was also the source of lubricating oils and vaseline, for which there was a great demand. As the crude oil contained 50 per cent. of this fraction, and often a much higher proportion, the distilling of every available supply to yield petrol must result in enormous volumes being thrown upon the market. The present shortage was probably due to the fact that the price obtained for it being so much less than that for petrol, all the time that there was a lack of transport facilities the light spirit was given the preference for shipment. But with the great increase in the number of tank steamers enormous quantities of fuel oil held in stock in many fields must become available, and the lecturer fully expected to see a marked drop in fuel oil prices during the next year, though whether it would ever come down again to the 40s. a ton that would enable the Diesel engine to compete with coal at 18s. in the best steam plant, save for special purposes, was another matter.

Both for steam raising and for heavy engine work shale oil could, at any rate, help to relieve the demand, though under ordinary conditions of working the grade of oil fitted for this purpose, which was yielded by the Lothian distilleries, would amount only to 50,000 tons per annum. But it was to be hoped that Government would do everything that could be done to encourage and, if necessary, subsidise the Scotch shale oil industry, as the proximity of the fields to the new naval base at Rosyth would render them an invaluable source of supply, while the unlimited demand for petrol, the possibility of cracking a certain proportion of lighting oil to augment it, and the probable gradual falling off in the lighting oil imported from America, would all tend to render possible a great increase in the Scotch industry.

The oils obtained from coal, and known as heavy tar oil, blast furnace oil, &c., were of a different character from mineral oil, as they contained oxygenated compounds of the nature of creosote and cresylic acid, which not only lowered their fuel value for steam raising, but also gave rise to acrid fumes, which in a closed stokehold were likely to cause smarting of the eyes and irritation to the throat. But by careful grading, and distillation oils from coke ovens, blast furnace and vertical gas retorts could be used in the Diesel engine by employing 5 per cent. of heavy petroleum oil to act as an ignition oil. The tar from horizontal retorts using light charges of coal and high temperatures, and also from inclined retorts, was, however, useless. The reason why ignition oil was needed was that in the Diesel engine the mixture of oil and air was ignited by the heat caused by the compression of the charge, and this temperature, *i.e.*, the ignition point, was governed by the amount of hydrogen in combination in the oil, upon which depended the ease with which it gave off inflammable gas on heating. Tar oil contained only about 8 per cent. of hydrogen, while petroleum contained as a rule over 11 per cent., so that the latter would ignite at a lower compression than would be needed for the former.

Joint Meeting of Naval Architects and Engineers.—Arrangements have been made by the councils of the Institution of Naval Architects and the Institution of Engineers and Shipbuilders in Scotland for a joint "summer meeting" in Glasgow from June 24th to 27th this year.

RAILWAY DEVELOPMENT IN SOUTH AFRICA.

THE report for 1911 recently issued by the General Manager of the South African Railways and Harbours, states that on 31st December, 1911, the open mileage of Government railways in South Africa was 7,546½ miles, whilst about 913 miles were under construction. Tests made in South Africa have shown the utility of mechanical stokers for locomotives, and the use of such an appliance will become more and more of a necessity as the size and power of the locomotives increase. Experiments are now being carried out in South Africa with a particular stoker which is an advance on any previous type tried, but further improvements will be necessary before it can be said to be of practical value. A new heavy goods engine of the non-articulated type was ordered during 1911, which will have a higher speed than the present Mallet engines. It is considered that the advantages gained by the ability to run mineral trains at high speeds do not compensate for the increased cost of maintenance of the permanent way which such practice entails. It would seem to be more desirable to develop the articulated or some other type of engine having much greater tractive force though only a comparatively low speed.

There is a splendid field in South Africa for some more economical means of providing locomotive power than exists at present, and the use of oil motors for branch and light lines is now being considered. South Africa also needs a cheap transport system which will enable some of the undeveloped country districts to be placed in regular communication with the railways. With this object the Railways Administration have been considering a scheme for the establishment of a motor road transport service equipped with two types of vehicle—one for passengers, parcels and mails, with a speed of from 12 to 20 miles per hour, and the other for goods traffic, with a speed of from 6 to 15 miles per hour. A telephone would run alongside the road and the whole service, as far as possible, would be conducted in accordance with railway methods. A branch railway would be built to replace any particular motor service as soon as the extent of the traffic was sufficient to justify such action.

The goods trains on the South African Railways are fitted with the "pin and link" type of combined draw and buffer gear, but the increased weight of trains has caused a good deal of damage, and a stronger type is now necessary. According to recent returns, the breakage of buffers amounts to over 4,400 per annum, and the parting of trains due to breakage of links or pins is over 1,500. When the change is made the provision of a satisfactory automatic coupling arrangement is very desirable. The passenger stock is being equipped with an automatic buffer coupler with satisfactory results, but the provision of a suitable coupler for the goods stock is a much more complicated matter, and it will probably be necessary to appoint a special committee to consider the question. Several types have been given practical trials, but none have yet fulfilled the requirements.

The results obtained from the two engines built at Durban have convinced the Chief Mechanical Engineer that the policy of building locomotives and boilers in the Durban and Salt River workshops should be considerably extended as soon as these shops have been enlarged. Schemes for enlarging and improving the equipment of these shops have been put forward. It is estimated that the average annual requirements of locomotives and rolling stock for renewals alone, and apart from the additional stock required for new lines, will amount to 60 engines, 80 coaches and 560 wagons.

A Large Armour Press.—There is at present being constructed by Messrs. Davy Bros., of Park Ironworks, Sheffield, a huge armour-plate bending press, which will have a power of 12,000 tons, for use at the Grimesthorpe Works, Sheffield, of Messrs. Cammell, Laird, & Co. A 180 ton overhead travelling crane is also being erected at Grimesthorpe, to be used in the moulding department in place of a 120 ton crane. Further, an additional bogie bottom furnace is being put down for dealing with the largest forgings made, such as gun jackets, and extensions of the steel making plant are being carried out.

A MODERN DESIGN OF BLASTFURNACE.

There is at present under construction at the works of the Maryland Steel Company, U.S.A., a new blastfurnace embodying several novel features. The arrangement is shown in the accompanying illustrations, for which we are indebted to "The Iron Age." The construction adopted represents a compromise between a thin lined and an internally cooled thick lined design. The hearth is enclosed by a heavy rolled steel jacket, cooled by vertical water-cooled staves, and the bosh is cooled by rows of bronze plates retained in cast-iron holders. The mantel is of riveted steel plates, and the shell, of hearth steel plates, springs from the centre line of the columns, giving at this point a brick lining of 36in. It is drawn in sharply above the mantel, and at a point about 15ft. above the mantel the lining is 27in. in thickness. There are ten rows of cooling blocks, consisting of cast-iron segments with pipes cast in. The first four rows above the mantel have three separate pipes in each segment, and the remainder have two rows. The water connections are made so that if the water pipe in any segment should leak it may be cut out without interfering with the circulation of water in the remaining coils in the same segment. The top of the furnace is provided with four down-comer openings placed at equal distances around the tunnel head, and to resist the abrasion of the stock at the top cast steel plates 3in. thick are suspended from the top brackets and held in the shell by substantial stays both top and bottom. These castings are strongly ribbed to prevent warping.

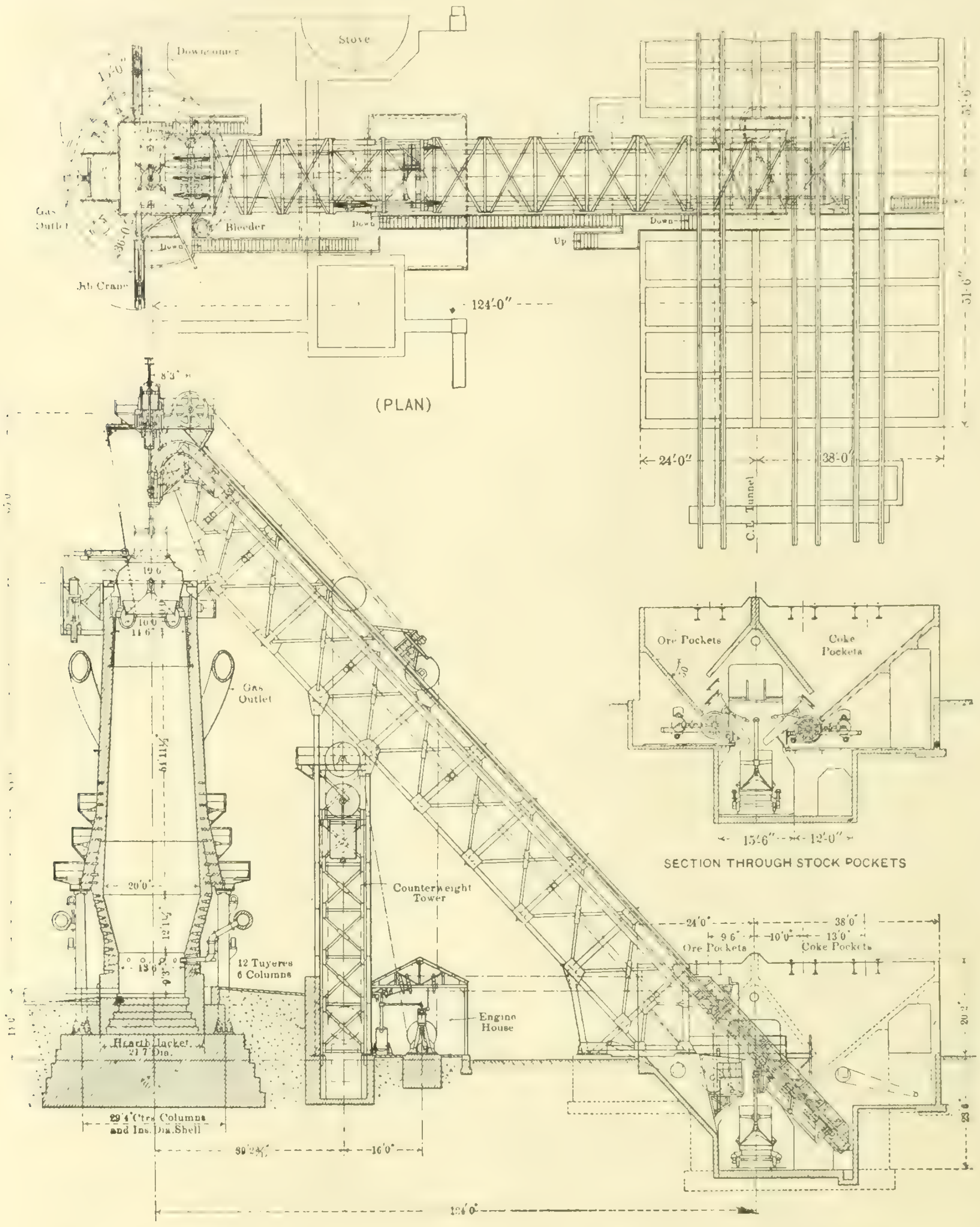


FIG. 1. SECTIONAL ELEVATION AND PLAN OF FURNACE AND SKIP HOIST, WITH SECTION OF STOCK POCKETS.

The tunnel head ring and supports, as shown, are formed together in a substantial steel casting, which gives a flat top that is as strong as a dome construction and entirely gas tight. This casting is made in four segments, shrunk together with heavy cast steel links, and fitting into the shell deep enough to provide ample support for the top castings and a very strong connection to the shell. The cast steel gas seal and main hopper are machined where they come in connection with this tunnel head casting, and in addition there is a deep pocket provided for packing with loam. The lip ring is held by eight heavy steel bars, which secure it firmly in place from movement either up or down. These bars extend through the gas seal and are keyed through bosses in same, so that the keys are always accessible and under inspection. All the top castings are of steel and extra heavy.

In place of the usual gas seal bell is a slide operated by a steam cylinder controlled by an oil cylinder. The main bell is hung from a steel cross beam and operated by a steam cylinder with oil control. To handle the top castings in making repairs, two jib cranes are provided. Only one bleeder is provided, and the four down-comers are brought into one connection in such a way that the angle of slope is always great enough to make the pipes self-cleaning. The main downcomer is brought into a large dry dust catcher tangentially to the shell, so as to give some centrifugal action, and from the dome of this dust catcher the gas is taken to two Kennedy centrifugals and thence to the gas mains. To secure a uniform distribution in layers a bucket skip with rotation was adopted, and at the outset an experimental bucket was tried out with various charges to determine the proportions best adapted to handling Mayari ore, which must be used at this plant, as the company has large interests in that Cuban district. A straight, cylindrical bucket was adopted, with a bell the full size of the cylinder, the experiments having shown that any revert at the bottom of the bucket either entirely holds back a part of the charge or delays its movement to such an extent that the time required to empty the bucket is prohibitive. The large bell necessitated making the bucket with an unusually large base, namely, 8ft. 6in.; accordingly the skip incline is unusually wide, and the gas seal so large that, as stated above, a slide is used instead of a bell.

The skip incline is unusual in being supported entirely independent of the furnace, and is merely steadied sidewise at the top of the furnace shell. The support for the incline serves as a runway for the counterweights, and the hoisting and counterweights ropes, while direct and simple, locate the

hoist on the ground level directly under the bridge proper, where it is most accessible.

To keep the bucket from swinging, a "Kennedy" parallel-motion skip car is used, with the unusual feature that means are provided for picking up and detaching the bucket automatically, regardless of the position it occupies after rotation, and also means for automatically locking the stem of the bucket to the car. These patented features are clearly shown in the illustrations, and it will be noted that the stem of the bucket is unusually long and terminates with a mushroom head. Since the automatic locking takes place in the first few feet of hoist, the bucket is rigidly locked to the skip car during practically its entire travel, and is considered as safe against detachment as a non-detachable bucket. To avoid damage to either the skip car or bucket in case of over-winding, breaking pins are provided in the safety latch over the top of the bucket stem, so that in case the hoist does not stop at the proper time, these pins will be sheared off and the skip car carrier will simply be forced down on the bucket stem without damaging anything. The skip car is of liberal proportions and so constructed that the axles with the wheels on them may be readily removed, and provision is made in the lower part of the skip incline for dropping one or both of the supporting rails, so that the entire skip car may be removed intact.

The liberal size of the skip incline, due to the large bucket, permits of the main bell and top casting passing up through it, and to this end the diagonal braces in the bottom lower cord are made removable and, as the skip car is well adapted to land anything on the centre of the furnace, the top changes can be made by way of the skip incline, although the jib cranes on top will handle anything.

The operator's stand is at the bottom of the skip incline, with a clear view both ways of the larry car track and a clear view up the incline. It contains indicators showing the seating of the skip bucket at the top and the movement of the gas seal slide and the main bell; also the usual sounding winches. The three levers controlling the motions of the hoist, the gas seal slide and the main bell interlock, and a proper cycle of

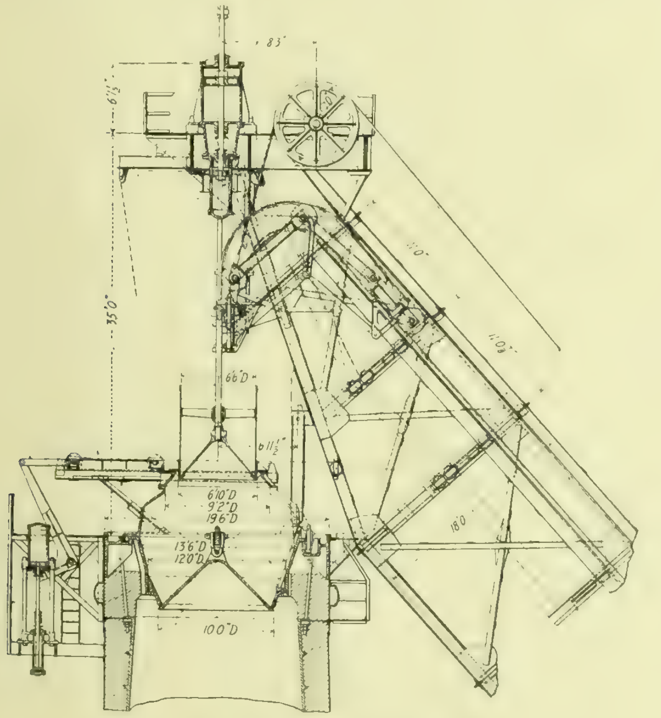


FIG. 2. SECTION OF FURNACE TOP

these motions is thus ensured without thought on the part of the operator.

The larry car carries two buckets on rotating tables and the usual equipment of four motors—two for running the car, one for rotating the tables, and one for lifting the load off the knife edge. The scale levers are extremely simple, four levers carrying the entire load and a fifth leading to the scale platform. The scale box is fitted with an indicator which shows the load approximately, and enables the operator to cut off the stock supply accurately.

The stock bins are of reinforced concrete with steel track beam. They are so arranged that the larry car tracks and all operator posts are well lighted and ventilated. They are lined with renewable cast iron wearing plates and fitted with feed rollers which deliver the stock directly into the rotating bucket. The coke is screened by feed rollers of unique design, which are illustrated in detail. The usual feed roller for screening coke is a steel plate drum perforated with holes about

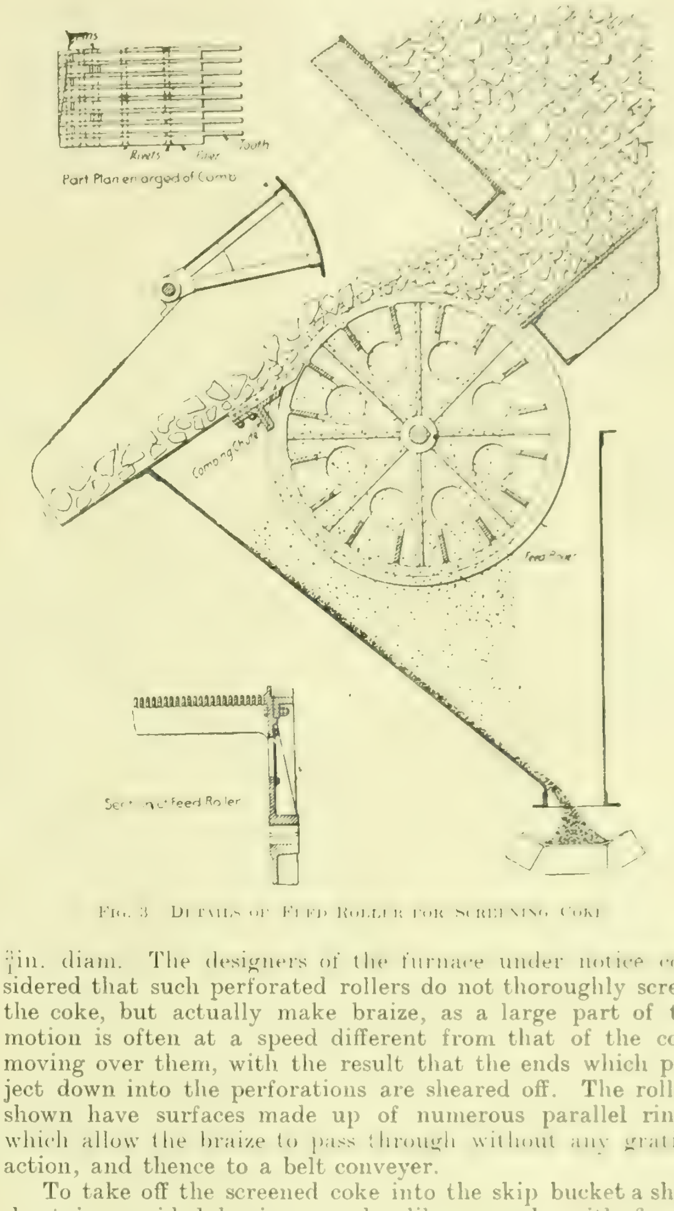


FIG. 3. DETAILS OF FEED ROLLER FOR SCREENING COKE

¾in. diam. The designers of the furnace under notice considered that such perforated rollers do not thoroughly screen the coke, but actually make braize, as a large part of the motion is often at a speed different from that of the coke moving over them, with the result that the ends which project down into the perforations are sheared off. The rollers shown have surfaces made up of numerous parallel rings, which allow the braize to pass through without any grating action, and thence to a belt conveyer.

To take off the screened coke into the skip bucket a short shoot is provided having an edge like a comb, with fingers extending into the spaces in the roller surface. This device keeps all the openings in the screening roller clear, and makes the whole an effective means of removing the coke dust from the coke. It is found so efficient that the quenching cars from the by-product ovens are dumped directly into the coke pockets and the handling and consequent breakage is thus reduced to a minimum.

Johansson Combination Standard Gauges.—In the article on this subject, which appeared in our last week's issue, the concluding paragraph on p. 144 should read: "In conclusion it should be stated that the agents for the gauges in this country are Messrs. C. W. Burton, Griffiths, & Co., Ludgate Square, Ludgate Hill, London, E.C.'

Fatal Overwinding Accident.—Thirteen men were killed on Friday last at Bolsover Colliery Company's new pit at Rufford, near Mansfield, through the overwinding of a water bucket containing 800 gallons of water. This heavy bucket crashed 160 yards down the shaft, where the sinkers were at work on a platform. Those who were not crushed to death by the bucket were precipitated into the water. There were 18 men at work on the platform at the time, and of these five got out, three of them being badly injured.

ILLUMINATION OF ENGINEERING WORKSHOPS BY GAS, ELECTRICITY, AND OIL.*

ELECTRICITY.

BY HAYDN HARRISON.

(*Continued from page 157.*)

THE illumination of factories and workshops by electric light having become common practice, it might be the opinion of many that there is little more to be said on the subject, but the science of illumination has advanced so materially during the last few years that to those who have studied it and who are in the habit of passing their time in engineering workshops, the systems of lighting they see adopted will often strike them as an abuse of a form of illuminant which, when correctly used, is ideal for the purpose.

It must be borne in mind that the work carried out in engineering workshops has to be of an accurate nature. This means that not only every detail of the work should be clearly visible to the worker, but also that such defects in lighting which might cause a strain on the nervous system should be carefully removed. Under these circumstances glaring lamps must be avoided. Illuminating engineers are now generally adopting types of reflectors which prevent the actual lamp filament being visible under working conditions. Moreover, these reflectors or shades so increase the candle power or useful rays in the required direction, that the cost of electric lighting is reduced to such a figure as to make it doubtful whether any other form of illuminant could compete.

Before dealing with the artificial illumination of any interior, it is wise to investigate the daylight conditions, as they considerably affect the requirements of the workers. For example, a series of recent tests show that the artificial illumination of some automatic screw cutting machines varied between 9 and 15 ft.-candles, whereas the daylight illumination on the same machines was only 3 ft.-candles. In another case the daylight illumination was 37 ft.-candles, the artificial illumination being 133 ft.-candles. This tends to prove that the workers prefer a higher degree of illumination than is sometimes obtained during the daytime, and those who have noticed how often a workman will employ an electric hand lamp during the daytime will, no doubt, have come to the same conclusion.

Most of you will have studied the very valuable Annual Report of the Chief Inspector of Factories and Workshops, especially the results of the careful observations and measurements of daylight and artificial illumination contained therein. Unfortunately, none of these results actually refer to engineering workshops, but for the purpose of comparison the machine shops of clothing factories offer an excellent example. These show that the daylight illumination of different parts of the benches varies from a minimum of 1·6 ft. candles to a maximum of 67 ft. candles, and under artificial lighting conditions from ·84 to 32 ft.-candles, in which case electric light was responsible for both the maximum and minimum results. It is also interesting to note that where dark materials are being worked the average illumination is well over 5 ft.-candles. The Inspector's report clearly brings out the fact that no definite minimum illumination has ever been aimed at, but he also points out the reason for this, namely, that such a minimum would have to be regulated by the Albedo of the materials worked upon, which varies so much in different factories that no specified minimum would be of much value unless it included this factor.

The Albedo factor of machine shop work must necessarily be very low, especially where iron is being worked; therefore, we may take it that the degree of illumination must be comparatively high. The Albedo factor can generally be conveniently measured, but in the case of machine shops it varies every moment, for instance, between rough iron and bright iron, but in no case is it likely to exceed 33·3 per cent., and is very often lower than 10 per cent.; therefore, for exact work the illumination must be three to ten times more than would be necessary for reading or writing. In America, where this subject has received very special attention, the following values are considered essential in machine shop working.

	Foot-candles.
General illumination only (where additional or special illumination of each bench or machine is provided)	1·5
Bench illumination	4
Machines (or machine shops with no local illumination)	6·7
Foundries, general illumination	3.
Power houses, general illumination	2·5

The above figures may be taken as a very good guide, and no doubt the point which will interest you most is how to obtain such results without depreciating the value of the illumination obtained by introduction of glare or other defects, and at the same time keeping the cost within reasonable limits. With reference to the question of glare, I cannot do better than refer you to the report of the Chief Inspector of Factories, where he states that "a system of illumination may be described as 'glaring' when it exceeds any of the limits specified in the following, namely: (*a*) If the ratio of intrinsic brilliancy of the source of light to that of the illuminated surroundings exceeds a certain limit, this ratio should not exceed a value of about 100. (*b*) If the absolute intrinsic brilliancy of a source exceeds a certain value. The brilliancy of the open candle flame (about 2·5 candles per square inch) might be taken as a safe limit. (*c*) If the angle between the direction of vision of the eye when applied to the work it is called upon to do (*e.g.*, when gazing at a desk, blackboard, or diagram on the wall, &c.), and the line of the eye to the source of flight is too small, this minimum angle may be provisionally assumed as 30°. (*d*) When the extent (apparent area) of the illuminating body is too large, the source should not subtend an angle of more than 5° at the eye."

From this it will be seen that the important points to be taken into consideration are mainly: (1) The position of the light unit. (2) Efficient shading. The importance of the above recommendations cannot be over-estimated, as they settle once for all the postulate that none of the more modern types of illuminants—such as gas mantles, incandescent electric lamps or arc lamps—can be used unshaded, and further, that many of the modern translucent shades are not sufficiently dense to come within the limits prescribed; on the other hand, where high candle-power light units, such as high-pressure gas lamps or electric arc lamps, are adopted, the density of translucent globes necessary to reduce the intrinsic brilliancy to 2·5 c.p. per square inch, would so materially reduce their efficiency as to rule such units out of order, unless a semi-indirect system of lighting was adopted. It is thus becoming a tendency of modern practice to adopt a system by which none of the light sources are visible, or in any case only those which being intended for general lighting (ample local lighting having been separately arranged for) may be comparatively low in intrinsic brilliancy.

In the American figures referred to, it will be noted that the general illumination was put at 1·5 ft.-candles. Your President suggested that in order that this paper might have some common basis of comparison with the others on the same subject, an example of this nature should be taken and that costs should be given. The example suggested is that of a workshop having two bays, one 250ft. long, 50ft. wide, and 30ft. high, given up to heavy machinery, the other 250ft. long, 30ft. wide, and 15ft. high, devoted to small machinery. There are certain conditions relating to travelling cranes in the large bay and belting in the small bay, which might affect the disposition of the lamps, but as the actual position of these is not defined, they can only be taken into consideration on general lines.

The writer in this case has taken for granted that the specified minimum illumination, namely, 1·5 ft. candles, applies to horizontal illumination on the floor in the case of the heavy machinery bay, and on the benches or tool beds in the case of the small machinery bay. As the reflecting value of the walls and ceilings has not been specified it is as well to leave it out altogether, and as the comparison is a matter of cost more than illuminating efficiency, I only propose to consider two simple methods of illuminating the different bays.

The large bay being lofty, namely, 30ft. high, there are few objections to the use of high candle-power units suspended as high as possible, so as to be well out of the line of sight of the

* Abstract of papers read before the Manchester Association of Engineers, January 25th, 1913.

workers, as it is obvious that the intrinsic brilliancy of such units will be higher than the regulations relating to glare would permit. In this case, as all the light is to be directed into the lower hemisphere, no better lamp could be adopted than one of the modern types of flame arc lamps. The width of the building being 50ft., it naturally follows that if a line of lamps is placed down the centre of the roof near the apex they should be spaced at a distance of 50ft.; thus, each covers an area of 2,500 sq. ft., the total area being 12,500 sq. ft., five lamps would be ample, and these could be conveniently run in series on any circuit between 200 and 240 volts, which pressure is now becoming usual in works.

To ascertain the candle-power of the lamps necessary to produce a minimum of 1·5 ft.-candles on the horizontal plane, it is only necessary to take the maximum distance of the sources of light from the likely point of minimum illumination which would be near the edge of the building, half-way between two lamps (provided there is no light reflected from the walls); this distance is 46·4ft., then the simplest method is to multiply the illumination by this distance cubed, and divide it by the height of the light source to allow for the angle of incidence, the result being divided by two, as the illumination is produced mainly by two lamps. The effect from those beyond them need hardly be included in the calculation. This calculation works out as follows:—

$$\frac{1 \cdot 5 \times 46 \cdot 4^3}{30} \div 2 = 2{,}437 \text{ candle-power.}$$

Thus, if the lamps produce, say, 2,500 c.p. at angles from 40 downwards, the necessary illumination will result. Actual practice has proved that a 500 watt flame arc lamp can be relied upon to do this; thus five such lamps, taking a total of 2,500 watts, will be sufficient.

The cost of running such lamps depends mainly on three factors: (*a*) Cost of electrical energy. (*b*) Cost of carbons and trimming. (*c*) Interest and sinking fund and repairs. For the purpose of comparison the cost of electrical energy is taken at one penny per unit, this figure being chosen for reasons stated later. The cost of carbons and trimming for this class of lamp is generally found to work out at ·3d. per lamp hour. Interest, sinking fund, and repairs are taken as 15 per cent. on the capital outlay, which, in this example, would be easily covered by £50 for the large bay. On this basis the cost of working works out as follows for 1,000 hours of lighting:—

(*a*) 2,500 Board of Trade Units at 1d.	£10	8	4
(*b*) Carbons and trimming at ·3d. per lamp hour	6	5	0
(*c*) Interest and sinking fund and repairs	7	10	0
Total for 1,000 hours..................	£24	3	4

Total cost of lighting bay per hour 5·8d.

The small machinery bay cannot be dealt with in the same manner, partially on account of the height being only 15ft., and more particularly on account of the different class of work carried on there. In this case the postulate is taken as 1·5 ft.-candles measured on a horizontal plane 3ft. above floor level, which roughly represents level of the benches, lathe beds, and similar machinery. For this class of work shaded lamps would necessarily be adopted, and the modern illuminating engineer would probably avail himself of one of the opaque patterns of reflector supplied specially for the purpose for use with tungsten lamps. These are generally designed to produce an even illumination when the light units are spaced at a distance apart equal to about twice the height of the lamps above the working plane.

If the lamps and reflectors were placed 13ft. from the floor level and 10ft. above the working plane each lamp would cover an area of 400 sq. ft.; thus, about 20 such fittings would be necessary. As with these fittings the light on the working plane is equal to double (or even more) the horizontal candle-power of the lamp, one 50 watt lamp in each fitting would give the necessary minimum horizontal illumination; thus, this bay would take 1,000 watts or ·133 watts per square foot. Working out the costs in the same way as the large bay, we have to consider the cost of lamp renewals which may be taken as 2s. 6d. per fitting per 1,000 hours, interest, sinking fund, and repairs at 10 per cent., which, allowing the capital cost as £30 for fittings and wiring, works out as follows:—

Cost of illuminating small bay per 1,000 hours:

1,000 Board of Trade Units at 1d	£4	3	4
Lamp renewals	2	10	0
Interest, sinking fund, and repairs	3	0	0
Total per 1,000 hours	£9	13	4
Hour	2·32 pence		

These figures are instructive for several reasons, the most important being the difference in cost between lighting with large and small units; the cost of lighting the large bay with a total candle-power equal to 12,500, or one candle per foot, is 2½ times that of lighting the small bay with 20 15 c.p. lamps, which in the reflectors give 100 c.p. in the desired direction, or a total of 2,000 c.p. The following figures bring this out more clearly:—

Large Bay. (12,500 *square feet floor area.*)

Efficiency of lamps in required direction	5 c.p. per watt.
Total candle-power allowed	12,500 c.p.
Candle-power per square foot	1.
Cost per square foot per 1,000 hours ...	·464d.

Small Bay. (7,500 *square feet floor area.*)

Efficiency of light sources	2 c.p. per watt.
Total effective light allowed	2,000 c.p.
Candle-power per square foot	·267.
Cost per square foot per 1,000 hours ...	·31d.

The writer has always considered that for the purpose of comparison the floor area forms an incorrect basis, for two reasons: (1) The height of the area to be illuminated must be taken into consideration, especially in workshops where large tools are used, which must be illuminated from top to bottom; thus, in the case of the large bay making it necessary to illuminate a cubical contents three times larger than that of the small bay. (2) The number of workmen employed in a building must necessarily mean a better illumination. This second reason is one that requires careful consideration, bearing in mind the different classes of workshops under review.

In the first part of the paper it was clearly brought out that an illumination lower than 5 ft.-candles would not be adequate, considering the Albedo of the materials. Should this illumination be necessary all over the works, the cost of illumination would be nearly three times as much as the figures given, but to give this higher degree of illumination where there is nobody to make use of it is obviously a waste of money, hence the reason why the system of local lighting is being generally adopted. The example of the small bay more closely approximates to the system of local lighting, and the economy is apparent; but let us suppose that 100 men are employed in that bay. It is obvious that it would be more convenient for the men to have 100 sources of light placed in a position to suit each of them. These sources might be made to give 50 effective candle-power over an area, say, of 10 sq. ft., which would then be illuminated up to a degree of 5 ft.-candles by placing the light source 3ft. above it. By this means a working illumination would be provided at nearly the same cost as 1·5 ft.-candles specified, which is barely a working illumination even when the Albedo factor approaches 100 per cent.

It appears, therefore, when considering the illumination of machine shops that the cost of illumination per man would be a better basis to work on, and is therefore worthy of careful discussion and consideration. The writer has considered the question from this point of view, and finds that a basis of 10 watts per man for local lighting, plus a small amount for general lighting, should prove ample for general work, provided, of course, that suitable efficient opaque reflectors are adopted.

When going into the question of cost, it will be noted that one penny per unit was taken as a basis. It will, no doubt, be said by those opposed to electric lighting, that this cost is too low, but as most large works have either got their own generating machinery, or are supplied by power companies, it would be found that it was a very fair average. Even in smaller works using power, the cost of electric lighting is such as to make its adoption advisable. For example, in a works which came under the writer's notice, the lighting was

originally gas, and two gas engines were used for driving the machinery. About 200 tungsten lamps were installed and supplied with electricity from a dynamo driven off one of the gas engines. This has now been running for two years, and the proprietor states that the cost of gas for the gas engines has not appreciably increased, whereas the consumption of gas for lighting, which was previously a large item, has, of course, ceased.

Local lighting cannot be conveniently carried out by means of gas, as small light units, such as 20 c.p., are not efficient when using a flame source, and are, moreover, not adapted for use in efficient reflectors, on account of the heat given off and the proximity of the operator to the products of combustion. For reasons such as these, the public bodies naturally utilise and recommend the use of electric light. As regards degree of illumination, statistics have been obtained and published showing that defective illumination is often responsible for a decrease in output varying from 12 to 20 per cent. On the other hand, I trust this paper will have proved that efficient illumination can be obtained by the use of electric lamps, correctly spaced and shaded, at a cost which is probably lower than any other type of illuminant. This fact, combined with the valuable hygienic properties associated with electric lighting, has resulted in nearly all large employers of labour adopting this means of artificial illumination.

(To be continued.)

EXHAUST DISCS FOR STEAM TURBINES.

M. Delaporte, in "Revue de Mécaniqué," gives a description of a method of improving the efficiency of steam turbines by the employment of exhaust discs, and we are indebted for the following translation to the Proceedings of the American Society of Mechanical Engineers.

The last row of blades has always long blades as compared with the thickness of the distributed steam films, and the efflux comes out in an indefinite film, that is, without the separate stream lines being given an opportunity to expand in the direction of the axis of a blade. Owing to the immediate proximity of other vapour films, the films are not allowed to expand in the perpendicular direction $a\,b$ either (see Fig. A.) The guiding $a\,c$ prevents entirely any change of the direction of the films in the triangular space $a\,b\,c$; there can, therefore, be no expansion, and the pressure P at $a\,b$ is constant for the entire space, and particularly for the section below disc $b\,c$. As a result, the difference between P and the pressure p at the plane of outlet of the disc and at the exhaust gives only to the steam an acceleration A parallel to the axis of the disc; the change in direction produced affords the films the possibility to thicken in accordance with the increase of the relative velocity of the steam from V to V_1, but as far as useful work is concerned this acceleration is entirely lost, because it is not accompanied by a change in the moment of the quantity of motion with respect to the axis. There is, therefore, a certain limited pressure beyond which the turbine ceases to benefit by any further increase of expansion. This limiting pressure P is characterised by the relative velocity at the outlet of the disc being 360 metres (1,181ft.) per second, the output being

$$\triangle = 0.97\,Ps$$

where $\triangle$ is in kg. per hour, and s the total section open to the passage of the steam in sq. mm. (1 sq. mm. = 0·00155 sq. in.). Hence

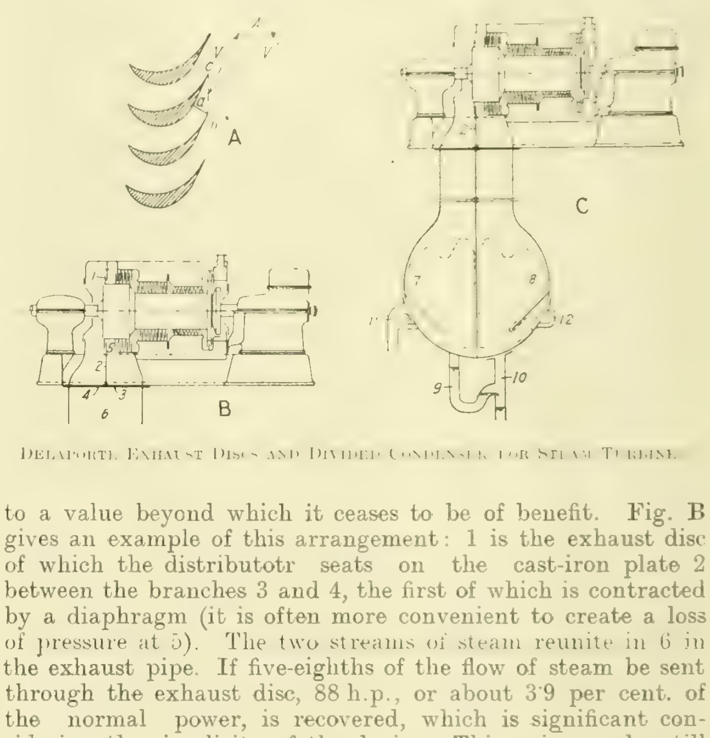
$$P = 1.03\,\frac{\triangle}{s}$$

The fact that there are many correct graphical proofs of the important advantages derived by turbines from reducing the pressure does not conflict with the above statement: all such proofs hold only for cases where the ratio $\frac{\triangle}{s}$ is small and the pressure P is below the pressure p of the condenser. But with the increase in the size of turbines which for economic reasons has not been followed by a reduction of their speed, the output $\triangle$ has increased, while the section s could not be increased at the same rate owing to its being limited by the strength of the materials used. A disc of ·0mm (say 30in.) in diameter, with blades 100mm. (3·9in.) long, and a coefficient of distribution λ' from 0·6 to 0·65 $(\lambda' = \frac{ab}{bc})$, Fig. A, represents about the limit of what can be done at 3,000 revs. per minute without sacrificing the safety of operation, and that gives to s a maximum value of about 150,000. The ratio $\frac{\triangle}{s}$ thus becomes an element which can no longer be neglected.

As an example the author considers a turbine driving a 1,500 kw. alternator at 3,000 revs. per minute. With average conditions of pressure, superheat and vacuum the steam consumption is 6·9 kg. (15·18lbs.) per kilowatt per hour; hence $\triangle = 6.9 \times 1{,}500 = 10{,}350$ kg, and

$$P = 1.03\,\frac{\triangle}{s} = 1.03 \times \frac{10{,}350}{150{,}000} = 0.71 \text{ kg.} = 1.009\text{lbs.}$$

If the cooling condenser water be taken at 16° C. (60·8° Fah.), and comes out of the condenser at 28° C. (82·4° Fah.), the pressure p at the entrance to the condenser will be approximately that corresponding, according to steam table, to a temperature of about 5° above the latter temperature or $p = 0.051$ kg. = 0·729lb. The expansion from 0·071 to 0·051 kg. is lost. But if a disc with $s = 150{,}000$ cannot take care of the entire steam at a pressure below 0·071 kg. another disc with equal section could drive off the steam at the pressure of 0·051 kg. if it had only to take care of a reduced amount of steam: this is the fundamental idea of the "exhaust disc." It is provided, like others, with a distributor, but this is placed between the two exhausts, and is traversed only by a part of the total flow of steam, the inlet connecting branch being contracted so as to limit the pressure in the main turbine



Delaporte Exhaust Discs and Divided Condenser for Steam Turbine.

to a value beyond which it ceases to be of benefit. Fig. B gives an example of this arrangement: 1 is the exhaust disc of which the distributotr seats on the cast-iron plate 2 between the branches 3 and 4, the first of which is contracted by a diaphragm (it is often more convenient to create a loss of pressure at 5). The two streams of steam reunite in 6 in the exhaust pipe. If five-eighths of the flow of steam be sent through the exhaust disc, 88 h.p., or about 3·9 per cent. of the normal power, is recovered, which is significant considering the simplicity of the device. This gain can be still further improved by modifying the condenser arrangement somewhat. As shown in Fig. C, the partition 2 is extended through the exhaust pipe right into the condenser which it divides into two parts. With regard to the circulation of water, the nests of tubes 7 and 8 are disposed in series with 7 receiving the fresh water. As a matter of fact, this arrangement results in there being practically two separate condensers of which one, viz. that receiving the steam from the exhaust disc (the author calls it the cold condenser) permits of obtaining a final pressure p_1 considerably below the pressure p of the other condenser, or the one that would prevail throughout the entire condenser if it were not divided. Notwithstanding the difference of internal pressures, both condensers may be supplied with water by the same pump. With the modified condenser an increase in efficiency up to 6·8 per cent has, it is stated, been obtained in actual tests.

MACHINERY FOR WARSHIPS.*

BY CAPT. C. W. DYSON, U.S.N.

In the selection of the type of machinery to be used in warships, the following points must be taken into consideration: (1) General character of the service which the vessel will be called upon to perform, whether she must keep the sea for long periods, cruising at speeds very much lower than her maximum speeds, or whether she will be called upon for very little slow cruising, but must be held in readiness for dashes at high speed from a base to any threatened point. (2) Greatest economy to be realised at the conditions under which she will be called upon to operate. This factor is important, not only from the standpoint of financial saving in reduced fuel cost, but in the greater ease of fuel supply due to the decreased demands. (3) Fuel capacity required by the demands of the service to which the vessel may be subjected. (4) Ease of upkeep of the machinery, and degree to which the vessel, so far as machinery repairs are concerned, can be made self-supporting. (5) Reliability of machinery when driven at high powers. (6) Minimum space and weight required for the propelling machinery. (7) Efficiency of propellers for manœuvring. (8) Minimum obtainable vibration of hull due to machinery in operation. (9) Effect of vertical position of centre of gravity of the machinery upon the time of roll of the vessel, in fixing the quality of the vessel as a gun platform.

The question of costs of the different types of machinery will not be considered in comparing the relative advantages of the types, and the relative values of turbine reduction gear, electric propulsion and internal-combustion engines for propulsion will not be dealt with, because they are still more or less in the trial stage and sufficient data are not yet available to allow of a fair comparison. Eliminating these three latter methods of propelling naval vessels restricts the choice of machinery for this purpose to the three following methods: (a) By means of reciprocating engines. (b) By means of steam turbines, impulse, reaction, or a combination of the two. (c) By means of various combinations of reciprocating engines with turbines.

Reciprocating v. Turbine Engines.—Formerly the favourite method of comparing the relative economies of propulsion of reciprocating engines and turbines was by comparing the water per shaft horse-power of the turbines with the water per indicated horse-power of the reciprocator, in this comparison all mention of the large difference between the indicated horse-power required in the one case and the shaft horse-power in the other being carefully neglected. The method of comparison in use to-day is the commercial one of "pounds of fuel per knot" at different speeds. From a study of the operating characteristics of battle-ships driven by each class of engine, the following conclusions seem justified, under present economic conditions and engine design practice:

Should the duties of a vessel be such that she is required to steam for long periods and long distances at speeds much lower than her designed maximum speed, a less fuel expenditure per day will be required, and consequently a greater cruising radius will be obtained and less frequent recoaling necessitated, should reciprocating engines be fitted rather than turbines for propelling purposes.

Should the vessel operate from a fixed base, only doing sufficient cruising to ensure that the machinery is kept in efficient condition in readiness for forced runs to any threatened point, the value of fuel economy at low speeds becomes minimised and, where the maximum speed of the vessel does not exceed 21 to 22 knots, either turbines or reciprocating engines may be used, the choice being dependent upon other factors than economies, which are practically equal at these speeds.

In other words, for the conditions (2) and (3), under which the American battle-ship fleet operates, the reciprocating engine is preferable to the turbine as a propelling engine. The Navy Department is, however, thoroughly alive to the advantages to be gained by adopting rotary in place of reciprocating motion in the main propelling machinery of the heavy vessels of the fleet, and, while recognising the present advantages held by the reciprocating engine in the matter of economy at low fractions of designed power, holds itself ready to discard the reciprocating engine as soon as the turbine designers can demonstrate by actual performance that their claims as to equality of economy at low powers with the older machine have been realised. It was with this object in view that the department decided to install impulse turbines in the "Nevada," and not because the engineers of the department were "wobbling," as has been charged.

The claim is frequently made by the turbine advocates that while the reciprocating engine, when new, is undoubtedly more economical than the turbine at small fractions of designed power, this advantage is soon lost in active service, due to excessive wear of piston and valve rings causing large losses through heavy leakage of steam, and that, on the other hand, the turbines, not being subject to such frictional wear, retain their original economy indefinitely. Practical experience with both types of engine in actual service comes very far from justifying this conclusion. In fact, with intelligent supervision, the reciprocating engine, particularly since forced lubrication has been applied, holds its superiority continuously.

When reciprocating-engined vessels visit the navy yards for their regular overhaul, the work to be done on the main engines is practically nil, as the machine shops and foundries of the battle-ships are of ample capacity to take care of all repairs that may be necessary except such as the fitting of a new cylinder or the repair of a fractured bedplate. The above remarks apply only, however, to ships fitted with forced lubrication, where the wear of bearings and journals has been practically eliminated.

When we turn to the turbine engines, however, the case is quite the opposite. Fully 99 per cent. of the troubles that occur with this type of engine are internal troubles, and consist of erosion of blades and nozzles, striping of blading, heavy corrosion of rotors, diaphragms and turbine wheels, causing destruction of balance. All of these troubles require a perfectly smooth haven in which to make repairs, and the majority of them require dockyard facilities.

Evidence of experience leads, then, to the conclusion that a battle-ship fitted with reciprocating engines for propelling purposes is much less apt to be forced off her station by necessary repairs to her engines than is one fitted with turbine engines.

As regards reliability, from the nature of the two machines it would appear to be safe to decide this condition as being distinctly in favour of the turbines, as this type of engine is completly free from all reciprocating parts held together by bolts and nuts. Experience with the "Delaware's" engines, however, lead to the conclusion that where proper care is taken to lock all nuts securely, and to effectively protect the engines against the shocks of reversal of direction of motion, the reciprocating engine can, even in this respect, be regarded as nearly on a par with the turbine in reliability.

The full-power 24-hour run of the "Delaware," made without preparation immediately after her arrival home from Chili, demonstrates this reliability of the present type of battle-ship engines very thoroughly. As stated, without any preliminary preparation of engines or machinery, the vessel put to sea, and upon getting well clear of the land a full-power run of four hours was started, during which time the vessel averaged 21·86 knots per hour. Without intermission the vessel continued on for 20 hours longer, averaging for the full 24 hours a speed of 21·3 knots, the ship automatically slowing down as the fires became dirty and the personnel fatigued. Upon the completion of the trial a radiogram was received from the commanding officer of the vessel reporting that not the slightest disarrangement had occurred to either the main engines or the auxiliary machinery, and that she was ready for immediate service.

The total heat units required to be absorbed by the boilers, both for Parsons turbines and for reciprocating engines, with battle-ships of the speed and power that now exist, is practically the same in both cases at full power. This indicates that, for existing conditions, nothing can be saved in the boiler-room weights or space by adopting turbines, as the same boiler-power is required in the two cases. In the engine-rooms, for these powers, however, the reciprocating engine has a decided advantage in both weight and space required, but this advantage would disappear should the necessary power to be developed be increased considerably above what is now asked for, and the advantage would rest with the turbine

* Abstract of paper entitled "Engineering Progress in U.S. Navy," read before the American Society of Naval Architects and Marine Engineers.

Should such an increase of power be called for in future designs, or should the ordinary cruising speed be made considerably higher than now used, the Navy Department would undoubtedly abandon the reciprocating engine and adopt one of its rotary rivals for the propulsion of its capital ships.

As regards the efficiency of propellers for manœuvring, the relation of the backing powers of the vessel as compared with the maximum full power ahead, and the time required from full speed ahead until the vessel is dead in the water, is taken as a comparative measure of this condition. When all boilers are in use, which in the case of the "Delaware" occurs at 25,000 i.h.p. for the main engine in the ahead motion, and for the "Salem" at 14,000 s.h.p. for the main engine in the ahead motion, the maximum backing powers can be obtained. In the case of the "Delaware" this maximum backing power amounts to 89·2 per cent. of the ahead power, while in the turbine vessel "Salem" it amounts to only 41·9 per cent. That is, at these points, the backing power of the "Delaware" is 2·13 times as great as that of the "Salem," both being expressed as fractions of the ahead power. At the maximum powers developed by the engines of the two vessels, the ratio of the percentage backing power becomes: "Delaware" - 2·27 "Salem."

These results are further corroborated by the backing tests of the "Delaware" and the "Utah" upon their preliminary acceptance trials, where, with the "Delaware" going ahead at 21 knots and the "Utah" at 20 knots, the times taken to bring the vessels dead in the water were, for the "Delaware," 1 min. 52 sec.; "Utah," 4 min. 44 sec. Backing power divided by ahead power is, for the "Delaware" 87·5 per cent., for the "Utah" 35·7 per cent. These results are still further corroborated by the destroyers, which can easily steam ahead at 16 knots under one boiler, but when called upon to manœuvre invariably, as a matter of safety, start a second boiler.

In judging the effect of vibration it seems only fair to base the decision upon the results of target practice of the vessels in service. If this is done, the decision could be given to the reciprocating type of machinery, as the "Delaware" has just won the championship of the battle-ship fleet, with the "Colorado," another reciprocating-engined vessel, standing second on the list. From these results it appears reasonable to state that, with well balanced reciprocating engines, no ill effects on gun fire should be expected.

Basing the choice between reciprocating engines and turbines, for battle-ship propulsion under existing conditions of speed and power, upon the above comparison of relative advantages of the two types, the advantage appears to rest most decidedly with the reciprocating engines, and the Navy Department has ruled accordingly.

Combination Systems.—In the search for economy of propulsion through a wide range of speeds, various combinations of reciprocating engines and turbines have been proposed, both by the Bureau of Steam Engineering and by the shipbuilders, but only one of the systems has as yet been authorised, and that one is for destroyers. It has not yet been tried out in service, but preliminary shop tests show a good gain in economy of the main propelling engines at cruising speeds. This system, as applied to the destroyers, depends entirely for its gain upon the greater efficiency of the reciprocating engine at the higher steam pressures over the efficiency of high-pressure turbines of the reaction type and the high-pressure nozzles of the impulse type of turbines, no advantage being gained from increased efficiency of propellers, as the reciprocating engines are on the same shafts as the turbines.

From some points of view this combination is undesirable, and the gain in service must be considerable to justify its retention. With the other combination systems proposed, calculations indicate that if the propulsive efficiency counted upon can be obtained, these systems will all be very much more efficient than either a straight turbine or straight reciprocating-engine drive at maximum power, will hold a big advantage over the straight turbine drive through all ranges of powers, and will hold its advantage over the straight reciprocating-engine drive until a minimum speed of about 11 knots is reached, when the efficiencies become equal. The "if" exists, however, and is caused by the danger of the currents thrown to the rear by the big reciprocating-engine screws seriously affecting the rate of feed and direction of flow of water to the turbine propellers. In addition, there may possibly be another source of loss due to heavy leakage of steam through the large change valves which must be fitted to control the paths of flow of the exhaust steam from the reciprocating engines.

In all of these systems, to adapt them to naval requirements, it is necessary to exhaust from the low-pressure cylinders of the reciprocating engines at a pressure of not less than 25lbs. absolute, when this engine is operating at full power, and to by-pass as few of the stages of the turbine as possible in order to obtain an increased economy of propulsion through a large range of powers.

Improvement in Engine Design.—The Parsons turbine, as it exists in our vessels to-day, is, with very few exceptions, the same as the turbines of this type which were fitted in the initial turbine vessel, the "Chester." The only improvements which have been made consist of changes in blade angles, particularly in the low-pressure stages, an increase in the number of rows of blades in these same stages, and the fitting of nozzles for the admission of auxiliary exhaust steam at several different locations along the steam path.

With the impulse turbine, however, the advance over the original naval turbines of this type, those of the scout "Salem" has been rapid. The number of stages has been very much increased, both in battle-ship and in destroyer turbines, a drum construction has been adopted for the lower-pressure stages, steam balance for propeller thrusts has been provided, cruising nozzles for low fractional powers have been fitted, and nozzles for utilisation of auxiliary exhaust are now supplied as in the Parsons turbines.

That these changes in turbines of the impulse type have been accompanied by increase in economy has been thoroughly demonstrated by experience with the machinery of the destroyers, the economy of the impulse turbine showing up nearly, if not fully, as good as that of the reaction type. No opportunity has as yet been offered to obtain a measure of this economy increase with the battle-ship types of impulse turbine, nor will such opportunity occur until the "Nevada" is ready for trial.

The steps taken in recent years towards increasing the economy and reducing the weight of reciprocating engines have been: increasing of the steam pressure at the engine, improvement in design of engine framing, increasing of piston speed, use of a slight degree of superheat, reduction of cylinder clearances, decreasing of frictional losses through the steam ports, provision of positive circulation of steam through the steam jackets, reduction of back pressure in the low-pressure cylinders, increasing of the ratio between low-pressure and high-pressure cylinders with consequent increased ratio of expansion of steam, and also the application of forced lubrication to all journals, crosshead guides, eccentrics and thrust bearings.

The following progress has been made in both reciprocating and turbine-engine systems: Condensing apparatus has been improved, resulting in higher vacuum; rational designs of feed-water heaters have been introduced, based on the amount of water to be heated and the amount of auxiliary exhaust steam available for heating purposes, instead of on the old rule-of-thumb method of allowing a fixed number of horse-power per square foot of heating surface; steam-piping design has been based on the actual rate of flow of steam through the pipes as determined by tests in service; feed-pipe losses have been reduced to a minimum; evaporators and other auxiliaries have been improved; high-speed, electric-driven, forced-draught fans for battle-ships and turbine-driven fans for destroyers have been adopted, and, finally, oil fuel has been adopted to a certain extent for both battle-ships and destroyers.

Considering the above changes in detail, the steam pressures at the main engines have increased since 1895 from 150lbs. gauge to 265lbs. gauge in the high-pressure valve chest, resulting in a decrease in the size of engine cylinders and in the size of steam piping for equal units of power.

Since the design of the "Oregon's" engines was laid down there has been a gradual increase in piston speeds used, from 900ft. per minute in that class of boat to 1,000ft. per minute in the "Delaware" class. This increase of piston speed has been followed by a decrease in the weight of moving parts and has aided in holding down the weight and height of the engine, although the stroke has been increased from 42in. to 48in.

In the use of superheated steam the Bureau of Steam Engineering (Navy Department) has been rather conservative. There are at present seven vessels in the naval service fitted for superheat, the maximum degree of superheat obtained at the boilers being 85° Fah., which reduces to about 60° Fah. at the engines. These figures are for full-power conditions, and an increase in economy of about 6 per cent. is estimated to be obtained. At 12 knots, the cruising speed, the saving by the use of superheat hardly exceeds 3 per cent. The first experiences with the vessels fitted with superheat were far from satisfactory, due to the rapid deterioration of the valves in the steam lines. These valves had cast-steel bodies and cast-steel valve discs with monel metal seats. The erosion and corrosion of the valve discs was very extensive, and in a short period of service it became necessary to replace the cast-steel valve discs with discs of monel metal. This substitution has been satisfactory and no further trouble has been experienced.

Reduction of clearance, decrease of frictional resistances of steam through the steam ports and reduced back pressures in the low-pressure cylinders have all resulted from a change in the design of engine cylinders and valve chests.

In the last ten years the ratio of low-pressure to high-pressure cylinders for triple-expansion engines has been increased from about 7 : 1 to 10 : 1, including clearances. This increase in ratio had been used previously in remodelling the engines of the "Cincinnati" and "Raleigh," with most excellent results. A serious mistake was made, however, in counting too much on the increased expansion obtained by fitting a smaller high-pressure cylinder than that originally installed, the steam pressure having been increased. The new high-pressure cylinder was made 24in. diam. and the ratio of low-pressure to high-pressure cylinder changed to about 11½ : 1. While the economy obtained with these engines was most excellent, the high-pressure cylinders were entirely too small and the engines have never developed the expected power.

By the adoption of forced lubrication for the main propelling engines the engine friction has been enormously reduced. All the journals are oil borne so that no metal-to-metal contact occurs. The result has been that the amount of adjustment and overhaul of the main engines has been decreased to a very large extent, and the men who would have been used for this overhaul work can now be used on the auxiliary machinery to good advantage. This decrease in wear of the bearings and the cushion provided by the oil, has resulted in a much better maintenance of alignment of the engines, has reduced shocks on the machinery and has reduced vibration due to these shocks. In addition, there is considerable saving in oil at ordinary speeds. At high speeds there still exists a heavy loss of oil, due to splashing on the cylinder heads and also to loss by evaporation from the hot surface of the lower heads. When first fitted the forced lubrication gave trouble, due to oil being drawn through the low-pressure piston-rod stuffing-boxes. In order to remedy this defect, stuffing-boxes fitted with steam seals have been supplied, and later reports indicate that where the steam seal is properly fitted no trouble of this kind now exists.

With the advent of the turbine for marine propulsion, if the full benefit of the new machine was to be realised, a high vacuum in the condensers became imperative. In order to obtain such vacuums the Parsons company originated the vacuum augmenter, and this addition to the condensing plant is used extensively in the naval service. In some vessels in the service, in place of the ordinary air pump with augmenter, air pumps of the dual type, as manufactured by Weir, have been fitted, while in other vessels both wet and dry-air pumps have been used. Of these systems, that with augmenters and also the dual type appear to give the greatest satisfaction in service, and, in addition, require less weight and space than the wet and dry system.

The improvements in design of feed heaters, steam pipes, and feed pipes naturally followed on the measurements of water consumptions of the machinery taken during the acceptance trials of the vessels. These measurements placed in the hands of the Bureau of Steam Engineering data of great value, and that bureau has attempted to use the full value of it in proportioning these important items. For instance, the feed heaters of the "Delaware" were, for lack of data, proportioned on the basis of so many indicated horse-power per square foot of heating surface, and the two heaters combined have a total heating surface of 2,100 sq.ft. In her sister ship, the "Utah," the same degree of feed heating is obtained with heaters having a total surface of only 512 sq. ft.

In the search for economy, the Bureau of Steam Engineering has adhered strenuously to the use of feed heaters with auxiliary exhaust steam as the heating medium, using any excess of exhaust in the low-pressure turbines or the second receivers of triple-expansion reciprocating engines. This utilisation of the auxiliary exhaust has not been to the taste of the turbine manufacturers, who prefer to use all of this steam in the turbines, depending for feed heat upon that derived from steam drains discharging into the feed tanks.

The improvements in evaporators consist mainly in the adoption of double effect connecting and in throwing open the gates to other than the standard bureau design, although these are not the only changes from former practice. Evaporator feed heaters using the vapour from the evaporators as a heating medium have been fitted, and vapour pipes, better designed for the amount they have to carry, are installed.

Until the adoption of electric-driven blowers for battleships and other large vessels and of turbine-driven blowers for destroyers and small vessels, the successful outcome of any heavy forced-draught run was always endangered by the unreliability of the blowers. Since the adoption of these types of blowers this danger of breakdown has been almost entirely eliminated, and, so far as the destroyers are concerned, the blowers may be classed as one of the most, if not the most, reliable of the auxiliaries fitted.

Oil Fuel for Destr yers and Battle-ships.—In deciding to adopt oil fuel for use on battle-ships and destroyers, the Navy Department took into account the following advantages which are to be gained by its adoption: Less fuel is required for any given radius of action; consequently less percentage of displacement and less bunker capacity are required for the fuel; boiler efficiencies are increased; fire-room force is decreased; deterioration of boilers is decreased, due to maintenance of more even temperatures; high power can be maintained for indefinite periods; there is less deterioration of the ship's structure because of the absence of water and ashes in the bilges; greater cleanliness is obtainable; the fuel supply can be more easily replenished both in port and at sea; less floor space is required for the development of a given power; and the steam supply can be more easily controlled.

In opposition to these undoubted advantages the following disadvantages exist; that fuel oil is less widely distributed over the earth than coal, that its unit cost is greater than that of coal, and that its storage involves greater danger of fire than attaches to the storage of coal. The reply to the first objection is that in time of war a fleet operating far from a base would depend upon fuel ships, anyhow, for replenishing her bunkers, and that oil can be carried in bulk as well as coal. Also, the bases where stores of oil can be kept on hand are as easily established as are bases for coal, and such oil bases would have, in case of danger of capture by an enemy, the additional advantage of being much more easily destroyed, together with their stores of fuel, than are coal bases. The second objection, that of excess cost of oil over that of coal, is more than counter-balanced by the advantages above stated. Finally, the third objection, that of danger from ignition of the ship's store of oil fuel, is very thoroughly guarded against by storing the oil in compartments remote from the boiler rooms and situated well below the water line of the vessel.

Upon deciding on the adoption of oil as a fuel for the naval service, the Bureau of Steam Engineering examined carefully all the systems for burning oil that now exist, and finally decided upon that of mechanical atomisation of the oil as the one most suitable for naval use. In this system the oil is pumped through heaters to the burners, within which it is given a whirling motion. The small central core of oil, discharging through the tip orifice with this whirling motion, the oil flies off and forms a cone of fine mist. This oil mist mixes thoroughly in the furnace with air which passes into the furnace through a cone register surrounding the burner, the register having adjustable openings and guide vanes so that the amount of air to each burner may be regulated and the direction of flow of this air be made slightly oblique to the axis of the cone of oil.

The success of the system depends almost entirely upon the proper handling of the air. Improper air regulation will produce a series of rapid explosions of oil in the furnaces with consequent destruction of their brick linings. With proper

handling the oil burns almost noiselessly, and the amount of smoke produced can be held under control.

In the first battle-ships fitted with oil fuel the oil was only fitted as an auxiliary fuel and was intended to be used as an aid in keeping up steam when the coal should be so low as to be remote from the fire rooms and so require excessive trimming. The results obtained with this mixed system are not to be rated as good nor were good results expected, as the furnace volumes of coal-burning boilers are too small to permit efficient burning of oil. Furthermore, when burning the oil and coal in combination, it is impossible to so regulate the air supply that each fuel will obtain the proper amount. This results in excessive production of smoke and no increase in steam production over coal alone.

REDUCING VALVES FOR HIGH PRESSURES.

The accompanying illustrations show several arrangements of reducing valves, the invention of Messrs. David Auld and Sons, Ltd., Whitevale Foundry, Rochester Street, Glasgow, for dealing with high pressures, such as air or gas compressed to a pressure of 2,000 to 3,000lbs. per sq. in. The valves are so designed that an arranged for uniform pressure is maintained in the service pipes independent of the fluctuations of the pressure in the main pipe. In the designs shown, in Figs. 1 and 2 the gas enters by the inlet A and passing the valve C flows away by the outlet B. The valve C is conical in form and is made of hard metal as also is its seat D. The valve seat D is maintained firmly in position by the plug E which is screwed into the casing F, its end being covered by the cap G, and the connection made airtight by means of suitable packing. The pressure fluid passing the valve C, passes direct to the outlet B, as shown in Fig. 1, and also by the hole S to the diaphragm chamber J, and as shown by Fig. 2 it passes through the holes S into the diaphragm chamber J, thence it flows off by the outlet B. The diaphragm K is acted on by the spring L, which is fitted with the ordinary pillars and adjustable cross head, to open the valve, which is closed immediately the pressure in the diaphragm chamber J rises above that arranged for and overcomes the pressure of the spring L, the valve being actuated by means of the lever M fulcrumed on the casing F. Referring to Fig. 3, a diaphragm N is employed to make an air or pressure tight joint and the pressure fluid is led to the diaphragm chamber J through the holes S and hollow valve spindle O.

The action in all the arrangements shown is the same and is as follows: The high pressure fluid entering by the inlet A opens the valve C and flows directly or through hole S to the outlet B. It also flows to the diaphragm chamber J, and when the pressure therein rises above that for which the spring L is set it acts on the diaphragm K to close the valve, and when the pressure in the diaphragm chamber J falls the valve is again opened by the action of the spring L.

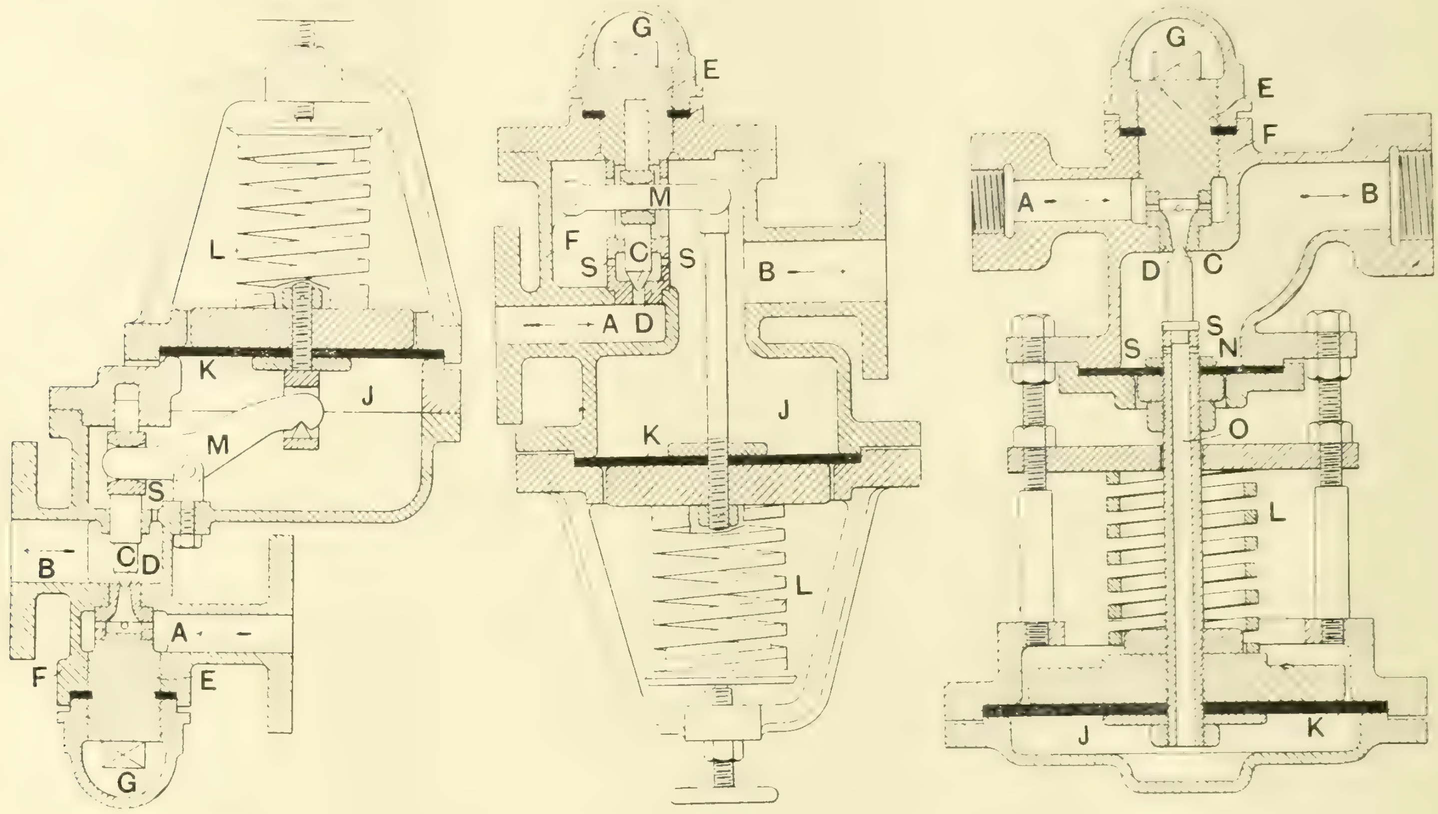


Fig. 1 Fig. 2 Fig. 3

Designs of Reducing Valves for High Pressures.

GAS TESTING IN MINES.

At a meeting of the Mining Institute of Scotland, held on Saturday last at Edinburgh, Mr. C. J. Wilson read a paper entitled "An investigation into the influence in variations of atmospheric pressure on gas caps." At the outset the author said that at the annual meeting of the Institute, held in April of last year, he had been permitted to communicate the results of some experiments which seemed to show that an increase of atmospheric pressure caused a decrease in the height of the gas cap. Redeeming the promise which he at that time gave, he had made a further set of tests, and these fully confirmed his original conclusions. Mr. Wilson in the course of his paper detailed at considerable length the nature of his more recent experiments, and maintained that, as his digrams showed, the distinction between percentages of gas likely to be met with in collieries became increasingly difficult as the atmospheric pressure increased. All his tests and the results they had disclosed brought him back to his starting point—namely, to the assertion that increase of atmo spheric pressure meant a decrease in the size of the gas cap

Wireless Telegraphy.—The governors of the Royal Technical College, Glasgow, have inaugurated a course of study in wireless telegraphy, under the guidance of Mr. Andrew Gray, chief of the technical staff of the Marconi Company, and an ex student of the college. There has been installed at the college a standard 1½ kw. Marconi marine wireless telegraphy equipment, with an aerial 325ft. long, at an elevation of 116ft., and other equipment. Lectures on electrical engineering will be delivered to the class by the professor of electrical engineering at the college, and there will be instruction in the use of the Morse system of signalling as applied to wireless.

INDEPENDENT STEAM CONDENSING PLANTS.

IN a paper read before the Yorkshire section of the Institution of Electrical Engineers on the 15th ult., Mr. W. A. Dexter considered a few of the later forms of surface and jet condensing plant, as used in connection with steam turbines driving electrical machinery, and also dealt with various types of air pumps, both reciprocating and rotary.

Entropy diagrams, he said, showed that for the non-condensing engine with steam at 165lbs. absolute pressure, we obtained 173 B.Th.U. per pound of steam; for the engine working condensing we obtained 248 B.Th.U., and where the steam was expanded to a vacuum of 28½in. we obtained 334 B.Th.U. per pound of steam, which showed a gain of 43 per cent. and 93 per cent. respectively over the non-condensing engine. These figures represented the theoretical gain, and showed the value of expanding steam below atmospheric pressure, and also the great gain in useful work which could be obtained by working an exhaust steam turbine in combination with a non-condensing steam engine.

For reciprocating engines of the low-speed type, as commonly used in the textile mills of this district, there was, he observed, no doubt that the attached condenser and air pump was the most efficient type; a high vacuum was not required, say 26in. at the condenser. For high-speed engines a vacuum of 26in. to 26½in. was quite sufficient for economical working. For steam turbines, and especially the low-pressure type, a high vacuum was really essential; but even here it was possible to aim at too high a vacuum for over-all efficiency where there was not a good natural supply of cooling water at low temperature. The most practical and efficient condensers for general conditions were the counter-current surface condenser, the low-level jet condenser, and the elevated self-draining "barometric" jet condenser with air pump. The surface type of condenser possessed many advantages over other types, though its initial cost was generally higher. The cost of operating the air and water pumps was lower, due to the fact that the condensing water was kept out of the vacuum chamber of the condenser.

A point which required careful consideration before deciding on a surface type of plant was the liability to corrosion or pitting of condenser tubes. This might be caused by local electrolytic action, stray electrical currents, &c., and it required only very slightly acidified condensing water to convey these electrical currents from one part of the tube to another. The author had found this trouble most prevalent where cooling towers were used. In certain cases the first analysis had shown the water to be almost pure and good for drinking purposes, but there had been a very slight acidity, quite sufficient to convey local electrical currents between the different metals forming the alloy of the tubes. Many different mixtures of tubes had been tried with only partial success, and the trouble had in certain cases only been overcome by periodically adding a certain quantity of lime to the water in the cooling tank, sufficient to produce a neutral solution. This corrosion and pitting trouble was also very prevalent where sea water was used for condensing. Zinc and sometimes mild steel plates were fitted into the water chambers of the condenser and connected by mild steel studs to the tube plates, the idea being that these plates would be of negative polarity to the metal of the tubes, and thus be gradually decomposed instead of one of the metals of the tubes.

He considered that the most efficient condenser was one in which the condensing water left the condenser at a temperature equivalent to the temperature of the exhaust steam; at the same time the condensed water should be withdrawn at as high a temperature as possible. In practice it did not pay to aim at so high a discharge temperature for the water, and the best temperature difference between the exhaust steam and discharge cooling water would depend on the inlet temperature of the water. Where there was a plentiful supply of cold water a greater temperature difference should be allowed than where cooling towers were used; also for lower degrees of vacuum, the temperature of the steam being correspondingly high a greater temperature difference should be taken than for a high vacuum.

For a given cooling surface the cheapest form of condenser was, he said, one of circular section, relatively small in diameter and long between the tube plates, but it would probably be found that a greater heat transmission per square foot of cooling surface could be attained by a condenser of different shape and design. The velocity of the steam as it passed through the condenser should be maintained as near as possible to the velocity at the inlet branch. Anything which would retard the flow of steam or cause eddies should be avoided. The volume of air which entered the condenser with the steam was but a small proportion of the total volume of the steam and air, but as the fluid passed through the condenser the steam became condensed until at the air pump suction branch or outlet of the condenser, the air formed a very large proportion of the air and vapour mixture, and as the pressure throughout the condenser should remain nearly constant, the area of the path of flow near the outlet might be considerably reduced, leading to a condenser whose cross-section was of wedge or pear shape.

The steam on entering the condenser should be directed equally over the whole surface of the upper row of tubes, and in its passage through the condenser each square foot of tube surface should condense an equal volume or weight of steam. To obtain this the steam inlet branch should be of large dimensions, following closely the contour of the top part of the condenser body. Plates might be fitted into the distributing chamber to direct the steam equally over the whole surface of the tubes. Except for comparatively small installations, separate air and water pumps gave the better efficiency. Three-quarters of an inch outside diameter was the standard used by most manufacturers for the tubes, but where the water was more or less dirty, it might be necessary to increase the diameter to 1in. or even more.

Where the cooling water contained a large amount of foreign matter liable to choke the tubes of a surface condenser, or contained salts which would form a scale on the tubes, and thus retard heat transmission, or was of a nature which might cause corrosion or pitting of tubes, or where it was not desired to collect the condensed steam for boiler feed, it would, he observed, be advisable to adopt a condenser of the jet type. It was a cheaper type of plant as regarded initial cost than the surface type, but, generally speaking, required more power for the operation of the pumps. In the low-level type, the injection water was usually drawn into the condenser by the vacuum, but it was necessary to withdraw the water from the condenser by means of a pump against a suction resistance equivalent to the vacuum, say, from 28ft. to 32ft. head. A separate pump should be used for dealing with the air and incondensable gases. Unless certain precautions were taken, there was a risk of flooding the turbine or engine with this type of plant. In the barometric type, except in very rare cases, it would be necessary to pump the water into the condenser, but no pump was required to extract the water, as the condenser, being fixed at a barometric height, would be self-draining. The air pump would be the same as for the low-level plant. The pumping power would be smaller for the barometric than the low-level type, as the full effect of the vacuum could be utilised in raising the water to the condenser. It was a safer and easier plant to operate, as, if properly designed, there was no risk of water flooding the exhaust pipe and thence getting back to the turbine or engine. It was more expensive than the low-level type on account of the longer length of steam, air, and water pipes required; also, on account of the long exhaust main, it would be necessary to design the plant for a little higher vacuum in order to maintain an equivalent vacuum at the turbine.

The highest heat transmission efficiency would be when the water which left the condenser was at the same temperature as the incoming steam. This result could be most nearly attained by arranging the steam to enter at the bottom of the condenser, the air and uncondensed gases being drawn off at the top. This gave counter direction of flow for the steam and water; the coldest part of the condenser was at the top and the hottest at the bottom; the water was being gradually raised in temperature during its passage through the condenser. For a good counter-current jet condenser and for the Leblanc multi-jet type with reasonably good air conditions, it was safe to allow for the condensate and injection

water being discharged at a temperature within 1 of the temperature corresponding to the vacuum.

The absolute pressure in a condenser was the sum of the pressure corresponding to the vapour tension of the condensed water and the pressure due to the volume of air present in the condenser. The air pump should, therefore, be of such a capacity and efficiency that it would effectively deal with the amount of air passing through the condenser, in a highly attenuated state or at low absolute pressure, thus closely reaching an absolute pressure in the condenser equal to the vapour tension of the condensed water. The pressure of air in a surface condenser greatly reduced the rate of heat transmission.

The amount of air passing through a surface condenser would be that due to leakage at glands, pipe joints, &c., and to the small amount present in the boiler feed water which would pass over with the steam; there would be a much greater amount in the case of a jet condenser, as, in addition to the above, there was the amount of air present in the injection water, which latter might be from 30 to 60 times the volume of the feed water. The amount of air present in the feed or injection water might be anything from 1½ to 5 per cent. of the volume of the water. Particular care should be given towards eliminating air leakage. All pipe joints should be carefully made. Low-pressure engine glands should be very carefully packed, turbine glands should be water or steam sealed, the latter being preferable, and for high vacuum it was better to have all valve spindles water-sealed. The exhaust mains, if of cast iron, should be of close grained metal, and care should be taken in the fixing of chaplets when casting: piping built of mild steel plates, if well made, made the best job. In a high-pressure turbine installation kept in good condition, with the condenser fixed close to the turbine, the air leakage should be within, say, 6lbs. per 10,000 lbs. of steam, or the equivalent to what would pass through a 3mm. diameter expanding nozzle per 22,000lbs. of steam condensed. For a plant connected to a single reciprocating engine, the weight of air allowed for should be that equivalent to what would pass through a 4mm. or 5mm. diam. nozzle per 22,000 lbs. of steam condensed. Exhaust steam turbine installations required careful attention. The pressure in the engine low-pressure cylinder and the exhaust main up to the turbine should always be kept 1lb. to 2lbs. above atmospheric pressure.

The reciprocating wet air pump with foot, bucket, and delivery valves had, he said, mostly been used in the past in connection with low-speed reciprocating engines, and driven directly from the piston rod or crosshead, and had in recent years been almost superseded by the Edwards valveless suction pump. The principal objection to the former pump was the complication of valves, and especially the inaccessibility of the valves in the bucket. The Edwards pump was well known. Its main feature was its simplicity, there being only one set of valves, and these being in the delivery plate, they were easily accessible for attention and replacement. The volumetric efficiency of this pump fell rapidly at high vacuum when the air was very attenuated; similarly it dropped very much when the speed increased.

Much attention had recently been given to rotary auxiliaries, and especially to air pumps. In general, the rotary air pump consisted of a centrifugal water pump which was made to deliver water in jets or sheets through an ejector, the air and gases immediately surrounding these jets being carried along with the water by reason of the friction between the surface of the water and the air in contact with the same. In other cases jets or sheets of water were projected intermittently through passages in the pump casing, entrapping air between the intermittent plugs of water, the whole being discharged against atmospheric pressure by the energy due to the velocity of the water. Experiments had shown that a greater volume of air could be discharged by a given quantity of water when the air was entrapped between plugs or sheets of water than when it was drawn into the ejector by skin friction between the water and air. The velocity of the water being one of the main features of this system, it was essential that it be obtained with the least possible expenditure of power. The features above-mentioned were embodied in the well-known Leblanc pump. A Leblanc pump was essentially a high-vacuum pump, and where very large volumes of air had to be dealt with, the reciprocating type as last described would be the better, but for the very high vacuum required for turbines, it was a most suitable form of air pump. The characteristic of the Leblanc air pump was a water ejector, in which the necessary kinetic energy of the water was produced in the apparatus itself by a reversed turbine of partial injection. The great advantage of rotary air-pumps was their extreme simplicity and the small number of moving parts, usually only an impeller and shaft, and being adaptable for direct driving from electric motor, high-speed engine or turbine, all usual gearing troubles were eliminated.

There was no need to dwell in detail on circulating or injection water pumps of the centrifugal type. It was now possible to obtain high efficiencies W.H.P. B.H.P. with this type, and they lent themselves admirably to direct driving from electric motors or small steam turbines. Steam driven auxiliaries had a distinct advantage over electrically driven, in that they were not in any way affected by a disturbance of the electric supply. In the case of a single-unit plant the pumps could be started up before the turbine, and a full vacuum obtained in the condenser ready for the starting up of the turbine. This, of course, did not usually apply to a large central power station where there were always one or more generating sets at work.

THE CAUSE OF BLACK SKIN ON BRASS CASTINGS.

THE influence of sulphur on brass and composition sand castings seems to be little understood. It is, says "The Brass World," one of the elements rarely determined by the chemist and it is generally considered as a substance inert and not worth taking into consideration. It is not so, however, and sulphur is an element that should be carefully watched, if any supervision of the metal is to be undertaken, as some of the mysterious and accompanying troubles of the brass foundry may be laid at its door. Sulphur causes three difficulties in sand castings: (1) Blowholes in the castings; (2) dirty metal; (3) dark or black skin on the surface of the castings. It is believed that much of the difficulty experienced from the use of scrap metals is really due to sulphur. Users frequently say: "We have had such and such an ingot metal analysed and it comes up to specifications, but we cannot use it. The castings are not like those made from new metals." The reason for this is that whoever made the analysis apparently overlooked the sulphur and it would probably have been found in the ingot metal made from scrap and not in the new material; and it would account for the difference. The chemist was to blame. G. H. Clamer, the well-known metallurgist, in his paper on the "Electric Melting of Copper and Brass," makes the following remarks in regard to the influence of sulphur on brass and copper: "I am firmly of the opinion that many of our failures, which we have ascribed to oxygen, are in reality, due to sulphur. I have made some investigations along these lines, and have found that in the most careful crucible melting in coke-fired furnaces, the metal will take up from 0·02 per cent. to 0·05 per cent. of sulphur. Copper has the greatest affinity for sulphur of any of our metals, outside of manganese, and naturally, it tends to absorb it if brought in contact with sulphur carrying gases. Sulphur accumulates each time the metal is melted, and this accounts for the dark skin on re-run castings, as compared with those of first melt metal." These remarks are very pertinent to the case and indicate that sulphur is an injurious element in brass. The oft-repeated statement that "scrap is not as good as new metal" seems to depend entirely upon the sulphur content. Much of the scrap on the market has been melted over and over again, how many times cannot be ascertained, but the fact remains that each time it is melted it absorbs sulphur and does not part with it. If new metal and scrap show the same chemical analysis, then they are the same, for copper is copper and tin is tin. If a chemist fails to report sulphur and the analysis of each is, therefore, identical, then it is not surprising that consumers make the above statement. Our contemporary advocates, therefore, that sulphur be one of the elements taken into consideration in specifications, as it has a far greater influence on sand castings than is generally appreciated.

The Institution of Mechanical Engineers. — The following paper (for discussion in writing only) is now ready for distribution:—"The Design of Volute Chambers and of Guide Passages for Centrifugal Pumps," by Prof. A. H. Gibson, D.Sc., Member of University College, Dundee.

WALLACE'S CONTINUOUS INDICATOR STROKE DIAGRAM ATTACHMENT.

THE accompanying illustrations show a form of indicator attachment made by the Crosby Steam Gauge and Valve Company, 147, Queen Victoria Street, E.C., for securing a continuous stroke diagram from opposite ends of heat engine cylinders.

The ordinary indicator diagram is commonly accepted to be a measure of the work done on an engine piston during two strokes or one complete revolution of the crank shaft; but actually this is seldom, if ever, the case; the diagram, in fact, only representing the work done on one side of the piston during one revolution. To determine the actual work done it is necessary to have diagrams taken from both sides of the piston simultaneously, though this is not enough when it is required to know the work done during any revolution of the crank shaft, or any stroke of the piston over a given period. For a correct result the diagrams must be taken from both sides of the piston, not only simultaneously, but continuously over the given period, and be obtained in such a manner that the diagram at any instant on one side of the piston may be coordinated with the diagram at the same instant from the other side of the piston. By means of the attachment illustrated, stroke diagrams in strict accordance with these requirements may be obtained, and their value will be at once apparent in all cases where a variable load runs at a variable speed, as in winding and rolling mill engines.

In these cases it is difficult with the ordinary indicator to determine the true average power developed, and more difficult still to say what the actual maximum or minimum power is. With the attachment illustrated, each pressure line is a true, undistorted record of the pressures on the piston, but the combination of the two pressure lines introduces a slight error due to the fact that the two indicator pencils cannot be brought into the same vertical plane. This error, however, is negligible and within the errors of the indicators themselves when the mean effective pressure is taken over a complete stroke, while the error may be corrected if desired by measuring a vertical ordinate between the two lines at the same distance on either side of the vertical as were the indicator pencils when the diagrams were taken.

The attachment, which may be fitted to any two Crosby indicators, whether of the inside or outside spring type, consists, as shown in Fig. 1, essentially of two parts (1) a stationary magazine drum with a roll of paper about 100ft. long, fitted upon a bracket arranged to couple the two indicators together; and (2) a special clutch drum which has to be mounted instead of the ordinary drum on one of the indicators to which the attachment is fitted. This drum is actuated in the usual way from the engine reducing gear, but only moves in one direction, withdrawing the paper strip from the magazine drum and winding it on itself with a speed at all times proportionate to that of the engine piston. An automatic stroke-recording device is provided which records on the indicator paper strip each reversal of the direction of motion of the engine piston.

Further, an electrical or mechanical "timing" device may be fitted, if desired, for recording "time" on the indicator paper strip; this is especially valuable where the speed of the engine varies irregularly, as by its means the piston speed at any instant may be ascertained with great accuracy.

A double 3-way cock connection receives the two indicators, and is designed to allow either indicator being put in communication with either end of the cylinder. When continuous diagrams are being taken, each indicator is put in communication with the end of the cylinder nearest to it, but if it is desired to take ordinary diagrams these may be obtained on the indicator drum which is retained in position, and can be put into communication with either end of the cylinder at will. The connection fixes the indicators at the right distance apart to receive the attachment, and allows of the indicator pencil levers being brought as close together as possible without touching. The resulting diagrams are not of the closed form, characteristic of the ordinary diagrams, but appear as two sinuous lines crossing and recrossing each other, and are such that the distance between the two lines at any point represents the effective pressure (either positive or negative) on the piston at that moment. The position on these stroke diagrams corresponding to the end of the stroke of the engine may, on account of faulty valve setting, not be self-evident, but the stroke recording device provides a means by which this can be accurately known, and it also eliminates any error which might arise from the slight lengthening of the diagram due to the increased thickness of the paper on the clutch drum as it is wound on it.

The calculation of mean effective pressure, and indicated horse-power from continuous stroke diagrams is made as follows: Fig. 3 being taken as a representative continuous stroke diagram from a double-acting steam engine, perpendicular lines are drawn at the points corresponding to the ends of the stroke, as shown by X-1, X-2, &c. The form of the stroke record differentiates one stroke from another, so that, by a simple inspection at the time the diagram is taken, or at any time if the method of connecting the attachment to the reciprocating part of the engine, is known, the up and down or forward and backward strokes may be differentiated.

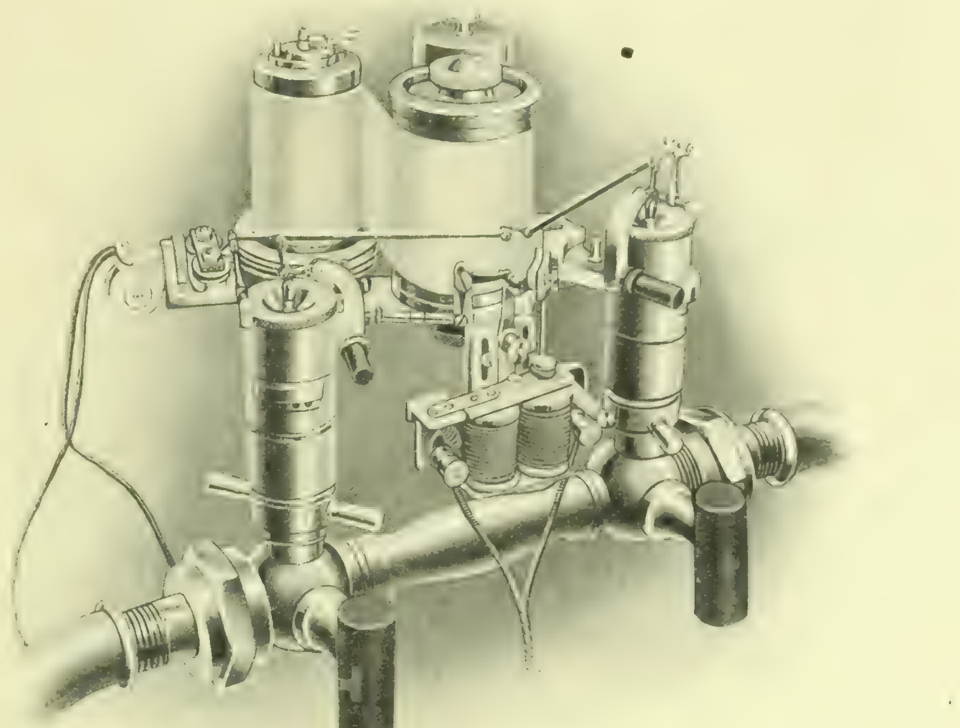


FIG. 1. WALLACE'S CONTINUOUS INDICATOR STROKE DIAGRAM ATTACHMENT.

Suppose the stroke 1-2, Fig. 3, represents the forward stroke of the piston, it can be seen at once that the pressure acting on the back side of the piston is represented by the dotted line, and that on the front side by the plain line, and that the motion of the piston is in the direction indicated by the arrows. Neglecting for the moment any correction necessary for the area of the piston rod, and the fact that the two indicator pencils do not move quite in the same vertical plane when tracing the diagram, the perpendicular distance between the two steam pressure lines represents, to the scale of the indicator spring, the effective pressure on the piston at any part of its stroke. When it is desired to take into account the area of the piston rod which reduces the effective area of

the piston on one side it is only necessary to multiply the forward and backward pressures into their respective piston areas and take the algebraic sum of the quantities so found.

Considering now the mean effective pressure and neglecting as before the area of the piston rod, the area A B G, Fig. 3, represents the work done on the piston, and the area B N C, the work done against the piston during the forward stroke. Similarly, the areas H K C N and K D L represent the work done on and against the piston during the backward stroke.

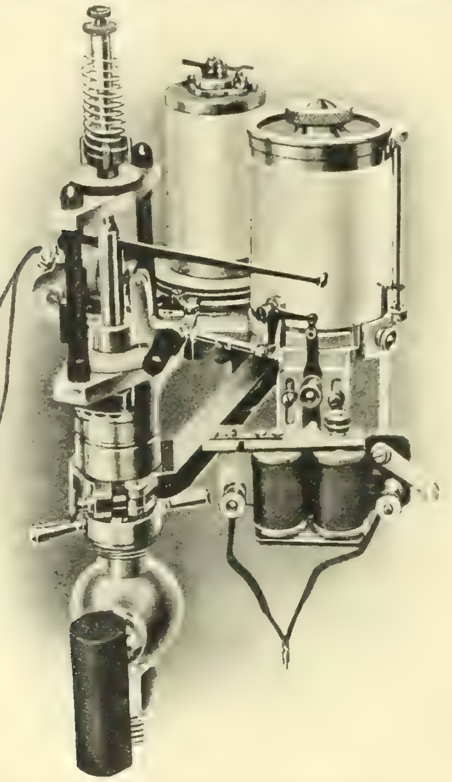


Fig. 2.—Wallace's Continuous Indicator Stroke Diagram Attachment.

The net work during each stroke is, therefore, the algebraic sum of the positive and negative areas, and the most convenient method of finding this is by means of the planimeter. The allowance for area of piston rod is made in the usual way.

Having found the mean effective pressure, the indicated horse-power may be determined in the usual way, but whereas with ordinary indicator diagrams the piston speed must be determined separately, and when the speed is variable *the average speed* only can be found with accuracy, these stroke diagrams enable time to be recorded simultaneously with the pressure diagram and stroke record, so that the piston speed at any instant or during any particular stroke or revolution can be found with perfect accuracy.

Figs. 4 and 5 represent continuous stroke diagrams taken from two-cycle and four-cycle gas engines, Fig. 4 representing a two-cycle diagram and Fig. 5 a four-cycle diagram.

The two-cycle diagram may be dealt with in the manner already described. The area A B C represents the work done on the piston during the explosion stroke, and the area B D E that done against the piston on the compression stroke, and the algebraic sum of those areas representing the net work done on the piston during one cycle. The gas and air pumps, if any, used with this type of engine should, of course, be indicated at the same time as the power cylinder, and the work done on the gas and air pump pistons deducted from the work done on the engine piston to find the net power available to overcome the frictional resistances of the engine and perform external work.

For the proper understanding of the four-cycle continuous stroke diagram, it is necessary to consider shortly the ordinary diagram taken from this type of engine as shown in Fig. 6.

It is the accepted practice to calculate the indicated horse-power from the mean effective pressure represented by the area A B F E, and to include with the frictional resistances of the engine the negative work represented by the area F C D, that is to say, it is agreed that a part of the negative work done during the exhaust, suction and compression strokes should be deducted from the total work done during the power stroke, and that another part of the negative work done during exhaust, suction and compression should be neglected and considered simply as forming part of the internal friction of the engine. The ordinary diagram lends itself to this arbitrary subdivision of the negative work because in practice it is impossible in most cases to measure the area F C D, except by taking subsidiary light spring diagrams. Referring to Fig. 5 it is evident that the net work done on the engine piston is represented by the algebraic sum of the five areas: A B E C, B D E, D F G, F H G, and H K L, of which A B E C and F H G are positive and the remainder negative. The net area found in this way will be less than that found in the ordinary way by an amount equal to the area F C D, Fig. 6.

In order to make the basis of calculation for these stroke diagrams the same as for ordinary diagrams, it is only necessary to draw a line, X—Y, Figs. 4 and 5, parallel to the atmospheric line, and at such a distance from it that it will cut the exhaust and compression lines at points equidistant from the same end of the stroke as at Q, Figs. 5 and 6. Then the algebraic sum of the areas A B O P, B M O, and N K R, Fig. 5, is equal to the area A B F E, Fig. 6.

In practice, and with the springs ordinarily used for gas and oil engine indications, the line X—Y does not differ sensibly from the atmospheric line, and, consequently, the mean effective pressure and indicated horse-power can be determined with the same facility and accuracy as in ordinary diagrams

ELECTRIC FUSE TESTING.

By A. A. Somerville.

In a recent set of experiments the author had opportunity to observe and consider the advantages and disadvantages of the electric fuse, as used at present. During this investigation several new points were brought out. Since a fuse is a conductor of such proportions that it will melt when the current in the circuit exceeds a certain prearranged value and thus protect the remainder of the circuit from the harm that would result from undue overload, it will be appreciated that its construction may be varied quite widely. Patents have been granted on such features as the composition of fuse metals, shape of fuse wires or strips, calibration of strips, insulating material surrounding the strips, mounting of fuses and chemical effects of oxides and fluxes, and the state of the art is rather complicated, thereby tending to promote involved litigation in patent causes.

The operation of fuses has been in many ways unsatisfac-

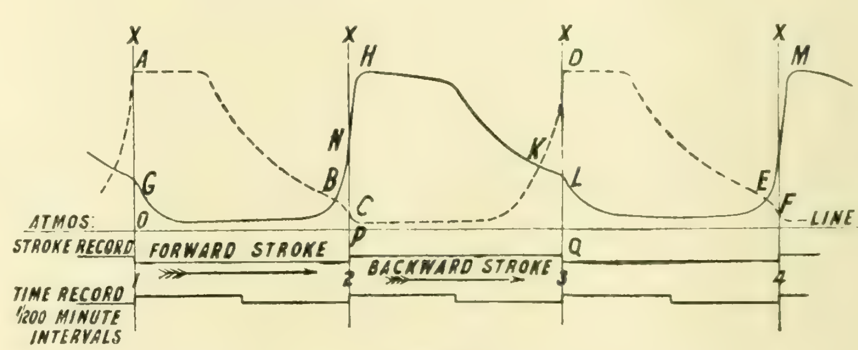
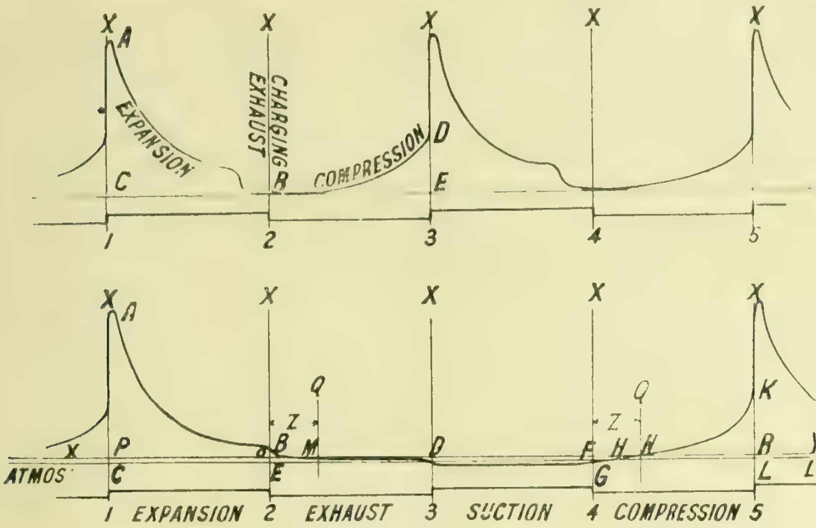


Fig. 5.

tory; the current at which they would blow has always been indefinite and liable to change with the age of the fuse. Generally the carrying capacity of the fuse increases with time, because repeated annealing renders the fuse metal a better conductor. However, the repeated heating and cooling may loosen some of the contacts, thereby making a high-contact resistance which will become unduly heated and thus cause the fuse to blow even when the current is below the normal value. In spite of their faults fuses are invaluable for the protection of small circuits where the cost of circuit-breakers would be prohibitive. Most wiring rules require that fuses be used on every pole where a reduction in size of

wire takes place and in each branch where a tap is made off a main line.

Each particular type of fuse has its own place, and care must be taken that the type designed for each class of work is used for that work and that only. For instance, the small piece of copper wire connecting two terminals is the most dangerous fuse that can be used for ordinary work, but the fact remains that it is used frequently for temporary repairs. The same kind of copper wire several feet in length is found to be the safest fuse obtainable for a high-tension transmission line, and is used in such work. Unless the wire is long the arc will persist under high voltage and cause damage. The long wire exposed to the air or slightly covered will safely carry the normal load, and when fused it drops away entirely, thereby opening up a long gap and effectually breaking the arc that is started.



FIGS. 4 AND 5

Cartridge fuses differ from the preceding in that the fuse metal is surrounded by a tube of insulating material, and this tube is fitted with metal caps to slip into terminal receptacles of the holder. The fuse wire is soldered or riveted to these metal caps. It is this class of fuse that is now almost universally used on small lighting and motor circuits, and it was upon these that a thorough test was made by the author. After a series of exhaustive tests it was decided that almost any kind of wire may be used as a fuse. The fusing current of the wire depends not only on the metal of which it is composed, but also upon its surroundings, the state of its surface, and other factors. It is claimed that in time some metals become coated with an oxide, and that this holds the metal in place like a protective tube or sheath even after the metal is melted. It was to determine the effect, if any, of this film of oxide on the fuse metal that the following experiment was attempted.

Zinc, tin, copper, aluminium, and magnesium were the materials examined, and three insulating materials were tried around the fuse wire, namely, manganese dioxide, slaked lime, and borax. From the observation made the following conclusions were drawn: Any metal may be used as a fuse strip, and if conditions are properly adjusted the fuse will blow at a fairly definite overload and make a sharp, clean break in the circuit. The factors that produce ideal conditions differ with the various metals, but the controlling features are relative values of length, width, and thickness of the strip, together with the amount and kind of insulating powder surrounding it.

All metals make equally clean breaks when properly adjusted. However, it is slightly easier to work with the metals having the lower melting points, as the thermal insulation is not such an important feature.

The character of the insulating powders used around the fuse wire is without effect except in a thermal way, and the rate at which the powders radiate heat from the fuse wire determines its capacity. The chemical effect, if any, on the fuse wire is negligible.

The load or current that a fuse will carry depends upon the melting point of the metal used, the cross section, shape, and length of the conductor, size of the terminal plugs, and contents of the casing, should there be any, surrounding the fuse metal.

The carrying capacity of a fuse varies with the cross-sectional area and inversely as the length, on account of the variation in temperature gradient in the fuse. The carrying capacity increases directly as the size of the copper terminals, since they conduct the heat away; directly as the increase in melting point of one material over another, and as a function of the thermal conducting power of the powdered material surrounding the fuse metal.

Lastly, fuses at their best are very unreliable, and no two fuses, except by chance, will operate in the same way. If a dozen fuses supposed to be alike are blown under the same conditions, the deviation in time required to blow will usually be 25 per cent. of the average. It may be said that the unreliability of the fuse with respect to the time-limit specification is its chief bad feature. Although the advance made in the manufacture of fuses has been very marked recently, there is yet ample room for improvement.—"Electrical World."

IMPROVEMENTS IN GAS PRODUCERS.

SEVERAL novel arrangements of gas producers, designed with the object of preventing caking of the fuel, are shown in the accompanying illustrations, Fig. 1 being a sectional elevation of the lower part of a gas producer having a rotary base. Fig. 2 is a sectional elevation of the lower part of a gas producer having a rotary base as well as a revolving rail, and Fig. 3 a vertical view of a gas producer having a rotary body. Referring to Fig. 1, A is the grate or air distributor fixed to the revolving ash tray B, which together constitute the rotary base, the revolution of the same being effected by means of a toothed wheel H and a worm O. This rotary base is carried by means of rollers D, which in their turn run on an uneven rail E, which is higher at some parts than at others, as shown. This is divided into six equal parts, each part having its upper surface in shape of a curve, this curve being so constructed that the rollers during the revolution of the base cause the same to ascend into or descend from the body of

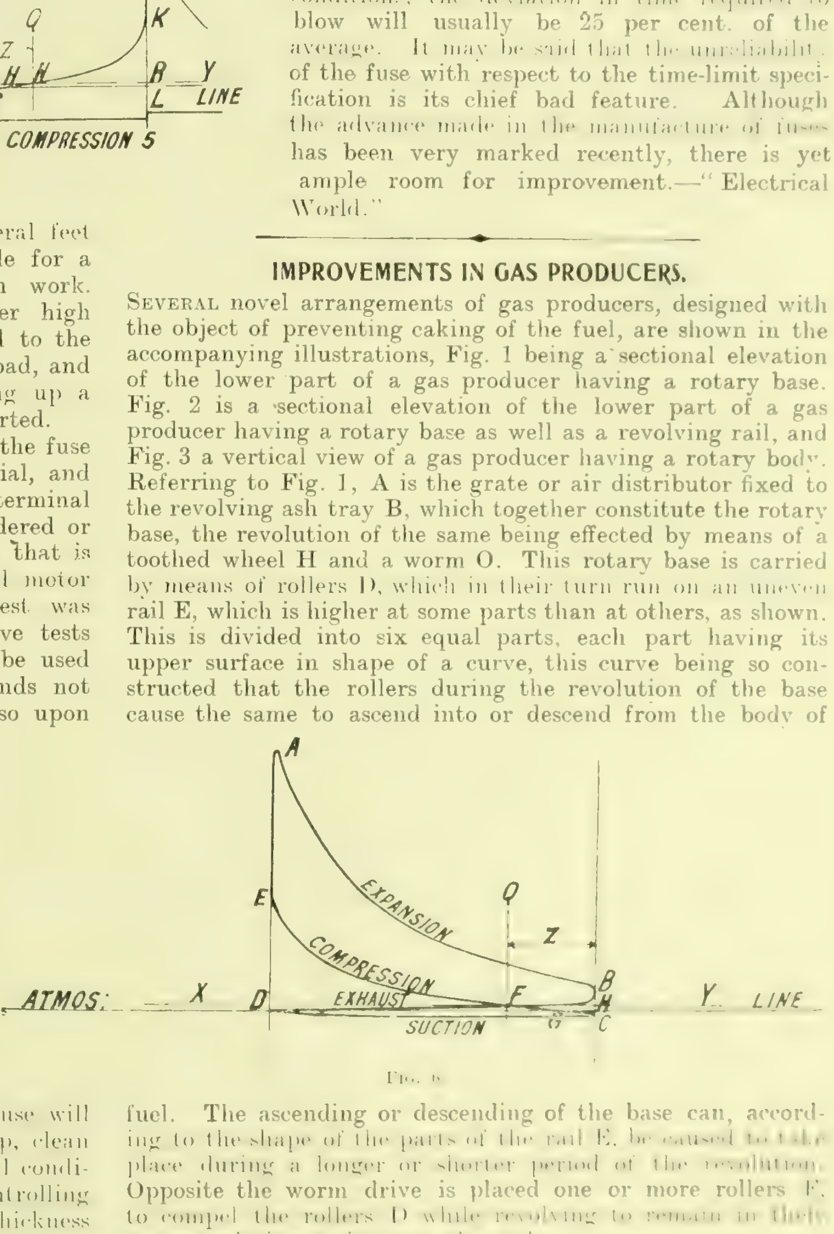


FIG. 6

fuel. The ascending or descending of the base can, according to the shape of the parts of the rail E, be caused to take place during a longer or shorter period of the revolution. Opposite the worm drive is placed one or more rollers F, to compel the rollers D while revolving to remain in their proper relative position on the rail.

Referring to Fig. 2, A is the grate or air distributor fixed to the ash tray B, which together constitute the rotary base which, as in the former example, is revolved by means of a toothed wheel H and a worm O. The rotary base is carried by means of rollers D which in their turn run on the uneven rail E. In this case, however, the rail E is mounted on

balls and in its turn rotated by means of a worm W and worm-wheel P. The drive for the base as well as the drive for the rail E can be adjusted in such a manner as to constantly regulate or periodically alter the speed of the rail E and the base independently of each other. Referring to Fig. 3, K is the producer body the whole of which, but not the top cover, is revolvable, and D the rollers which carry the same, and E is the uneven rail upon which the rollers run. This rail together with the drive L is mounted on girders M.

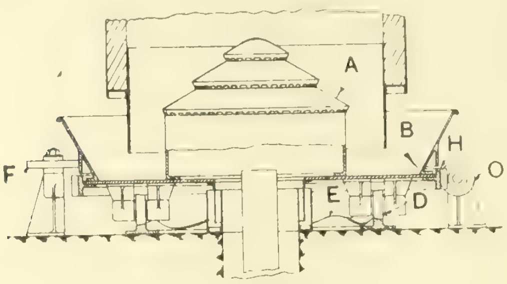


Fig. 1.

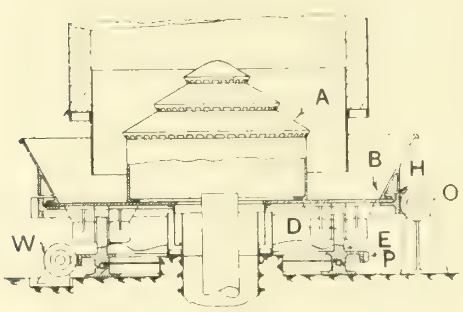


Fig. 2.

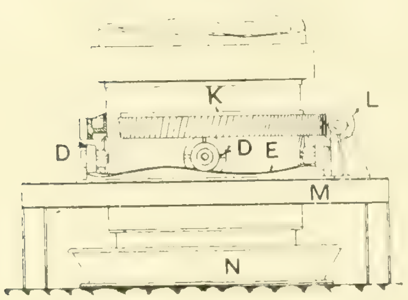


Fig. 3.
Improvements in Gas Producers.

The producer body may be revolved on an even rail, while the base N, with the grate or air distributor fixed thereupon, may be gradually raised and lowered. This may be done by carrying the base (which is prevented by suitable means from revolving) upon rollers, which in their turn rest upon a revolvable rail as shown in the lower part of Fig. 2. The arrangements described are, it should be mentioned, the joint invention of Mr. A. H. Lymm and Mr. N. E. Rambusch, Queen Anne's Chambers, Westminster, London, S.W.

Induction Motor Details.—At a general meeting of the North of England Branch of the Association of Mining Electrical Engineers, held on the 5th inst., in Armstrong College, Newcastle, Mr. W. Baxter, of Jarrow, read a paper on "Induction Motor Details." He alluded to induction motors for colliery work, and suggested that a feature which was neglected was the means of coupling the cables to the motors. He pointed out that the design should be of such a character that the connections could be easily and quickly made, and, what was of more importance, there should be means of readily uncoupling in case of breakdown. Mr. Baxter indicated methods for effecting this. The question of the windings of machines for rough work at collieries was touched upon, and illustrations were thrown on the screen of suitable machines. Other points dealt with by the speaker were designs of brush gear and brush-lifting devices; flame and explosion-proof motors for fiery mines were described, and particulars were given of self-starting motors.

TYPES OF MOTORS FOR STEEL MILL AUXILIARIES.*

BY B. R. SHOVER AND E. J. CHENEY.

The time has gone by when it was necessary to discuss the advantages of electric motors in steel plants. There are, however, a great many problems concerned with their application which are not yet fully solved. One of these is concerned with the proper type of motors to use. There is usually no question but that induction motors should be used for driving the main rolls, and that induction or synchronous motors should be used for pumps and various other machinery about the plant where comparatively large size motors are necessary. There is, however, a diversity of opinion as to whether the so-called auxiliaries should be driven by alternating or direct current motors, and there have come to be two recognised systems. These are known as the alternating current system, where no direct current is used, and the mixed system, where direct current is used for the small motors. There are a great many factors which must be considered in comparing the two systems.

In the first place, it is to be assumed that power will primarily be alternating current, as the transmission distances ordinarily preclude the use of direct current generators. It would, therefore, seem to be simplest and most efficient to step down to a suitable voltage through static transformers and use alternating current motors. The mixed system involves additional expense for motor-generator sets and entails considerable power loss due to the low efficiency of conversion. On the other hand, however, direct current motors are lower in first cost than induction motors, and a higher power-factor is maintained on the entire system where they are used. In the mixed system an increase in power-factor is effected by eliminating the lagging current of the induction motors, and, in addition, the motor-generator sets can easily be equipped with synchronous motors which will take a leading current from the line and offset part of the lagging current on the rest of the system. The increase in power-factor enables a reduction to be made in the size and cost of transformers and generators, and also increases their efficiency due to the lower currents which they are required to handle and to the decreased excitation required by the generators.

It is perfectly possible to prove that either system is superior by selecting the proper factors for consideration. The performance of both direct current and alternating current motors is quite generally known, but the various factors affecting cost and efficiency are not so well understood. In order to make as nearly as possible a general determination of these factors, it was decided to make an exhaustive study which should include a consideration of everything which might influence the result. To make the investigation thoroughly practical a plant of modern design, of which the complete plans were available, was selected for the study. This plant consisted of six merchant mills, comprising the ordinary run of sizes, and included the usual equipment of heating furnaces, shipping yards, &c.

The power was assumed delivered at 6,600 volts, 25 cycles. One large slow-speed induction motor, wound for 6,600 volts, was required for the main roll drive in each mill, the aggregate capacity of these motors being 7,700 h.p. In addition to this load there was about 800 h.p. in pumps, lights, &c., which would be alternating current in any case. Of the small motors on tables, benches, shears, cranes, shop tools, &c., there was a total of 182 motors and an aggregate of 4,973 h.p., giving an average of 27·3 h.p. per motor. On the all-alternating current system, it was assumed that all these small motors would be wound for 220 volts and power supplied by two sub-stations, stepping down from 6,600 to 240 volts, each sub-station having three 350 kilovolt-ampere oil-cooled transformers and suitable switchboard. On the mixed system it was assumed that all these motors would be wound for 230 volts direct current and that power would be supplied by two sub-stations, transforming from 6,600 volts alternating current to 250 volts direct current, each sub-station having one 750 kw. synchronous motor generator set and suitable switchboard.

Mill type motors were used on all tables, transfers, cranes, &c., and motors of open construction for shears, fans, shop tools, &c. The alternating current mill type motors were all

* Abstract of paper presented before the American Association of Iron and Steel Electrical Engineers.

of wound rotor type, and the corresponding direct current motors were either series or compound wound as required by the duty. The open alternating current motors were assumed to be of the squirrel cage induction type, and the corresponding direct current motors were assumed to be shunt wound. Suitable control equipment was determined in each case, most of the variable speed motors having magnetic controllers, but a few of the smaller ones having hand controllers. On the direct current system use was made, wherever possible, of the series type contactor. The constant speed induction motors were furnished with starting compensators having no-voltage and overload protection, and the corresponding direct current motors were furnished with standard starting equipments. In laying out the wiring, the load on the various feeders was estimated by taking into account reasonable load factors, and the size of all wires determined in accordance with the standard wiring rules, all wires being run in conduit.

The only instances where the motors might possibly need to be of different capacities for the different systems are in cases of hoist motors on the cranes. A careful study of the cranes was made, and it was found that the majority of them would operate at light loads almost all of the time, so that the same size motor could be used in each case, geared for the same light load speed, the speed of the alternating current motor being reduced on heavy loads by rotor resistance. On the billet yard cranes it was found advisable to put on larger motors for alternating current than for direct current. The total horse-power capacity given is for the mixed system.

The layouts having been carefully made, an estimate was made of the cost of each system. In these estimates the large motors, which would be alternating current in any case, were not considered, but all details which were in any way affected by the difference in the systems, including motor-generator sets, transformers, foundations, motors, control, cables, installation and wiring-up were included.

Having determined the apparatus located in the plant itself, a layout of the power supply system was made with a view to finding how much it was affected by the difference between the two systems. It was found that power should be generated at 6,600 volts and stepped up to 22,000 volts for transmission to the plant, where it would be stepped down again to 6,600 volts. The calculations of the power system will be followed through briefly, the all-alternating current system being considered first.

The sizes of generators and transformers are properly fixed by the maximum load conditions, and these maximum load conditions were carefully determined for the case in question. The duty of the mills under various conditions of rolling were studied, together with the characteristics of the large motors, and it was found that the maximum steady load which could be sustained for any length of time on the large motors, together with the other portions of load which would be alternating current in either case, amounted to 7,510 kw. at 84·7 per cent. power factor. The total small motor load was found to be 1,500 kw. on the 240-volt bus. Allowing for transformer losses on the basis of 98·2 per cent. efficiency at unity power-factor, this load amounts to 1,538 kw. at 70 per cent. power-factor on the 6,600-volt bus. Combining the two loads, we have a total on the 6,600-volt bus of 9,048 kw. at 82 per cent. power-factor, or 11,000 kilovolt-amperes.

As this is the maximum load, we can assume that it represents 25 per cent. overload on the transformers. Normal load on the transformers will, therefore, be 8,800 kilovolt-amperes, or 2,930 kilovolt-amperes for each of three transformers. It was, therefore, decided to use three 3,000-kilovolt-ampere water-cooled transformers for stepping down from 22,000 to 6,600 volts. Duplicate transformers would be used at the generating station for stepping up, and one spare would be provided, making a total of seven transformers required.

In figuring the transmission line it was found that the size of copper was fixed by the economical loss and not by the voltage drop. It will be unnecessary to go into the details of this calculation, but it will be sufficient to say that the line decided upon had a resistance of 0·762 ohms per phase. Knowing the kilovolt-ampere load and the resistance of the transmission line, and taking transformer efficiencies at 98·7 per cent. at unity power-factor, we have 286 kw. loss in the two banks of transformers and 195 kw. loss in the transmission line.

Adding the losses to the original load we come to the generator terminals with 9,529 kw. and 11,410 kilovolt-amperes or 83·4 per cent. power factor. Assuming we have four gas engine driven generators, we would have 2,382 kw. and 2,852 kilovolt amperes on each unit under the maximum conditions. These conditions may be assumed to represent 10 per cent. overload on the generators, and it was, therefore, determined to use four 2,200 kw., 85 per cent. power-factor generators. These machines would have a normal capacity of 2,590 kilovolt-amperes each, and at 10 per cent. overload a capacity of 2,850 kilovolt-amperes each.

Figuring as before, the transmission losses amount to 256 kw., the line losses to 157 kw., and we come to the generator terminals with a total load of 9,653 kw. and 11,250-kilovolt-amperes at 94·2 per cent. power-factor. This gives a load on each of four generators of 2,413 kw. and 2,562 kilovolt-amperes, which represents 10 per cent. overload. It was, therefore, determined to use four 2,200 kw. 95 per cent. power-factor generators, which would have a normal rating of 2,310 kilovolt-amperes, and at 10 per cent. overload a capacity of 2,550 kilovolt-amperes each.

From the above data the cost of the power system was estimated. Since the kilowatt load is so nearly the same there will evidently be no difference between the two systems in the gas engines or gas cleaning plant. The transmission lines are identical and there will be no practical difference in cost of switchboards. The only points of difference will therefore be in the generators and transformers, and they only were considered. The generators were assumed to be 83⅓ revs. per minute engine type, and the transformers were assumed to be water-cooled with full capacity primary taps for voltage adjustment. The costs for each system delivered and installed are as follows:—

	All- A. C.	Mixed.
Transformers	7,672	7,392
Generators	15,200	14,160
Total	£22,872	£21,552

So far, maximum load conditions, which determine the size of the apparatus required, and the first costs have been considered. In figuring efficiency and operating costs it is necessary to take load conditions which are fairly representative of the yearly average. The small motor load was considered the same as before, since little change would be made in it by varying conditions, provided the plant were working full time. The difference between maximum and average conditions lies in the different character of work in the mills and the consequent difference in load on the large motors, but this will not materially affect the small motor load, as all of the apparatus in the plant is assumed to be working at full output.

The average load on the large motors would, however, be considerably lower than the maximum, and the power-factor would be decreased in consequence. Careful consideration of all the factors showed a fair average of the main load to be 5,320 kw. at 80·5 per cent. power-factor, or 6,600 kilovolt-amperes. Adding the small motor load and the losses in transformers, line and generators, which were computed by taking into account the per cent. load and power-factor on each unit, the output required at the engine shaft was obtained. This was 7,663 kw. for the all-alternating current system and 7,678 kw. for the mixed system, or a saving of 15 kw. in favour of the alternating current system.

The real basis for comparison between the two systems is, of course, that of annual costs, which are made up of fixed charges, maintenance and power costs. In comparing the fixed charges the following percentages have been used:—

	Motors and control, per cent.	Other apparatus, per cent.
Depreciation	10·0	8·0
Interest	5·5	5·5
Taxes and insurance	1·5	1·5
Total	17·0	15·0

There would be no appreciable difference in maintenance between the two systems except on the motors. The maintenance figures were based on the records of motors of about the same capacity which had been in actual operation for some time and on which accurate records of delays and repairs

had been kept. These records were all for direct current motors, as no reliable records were available on alternating current motors for a sufficiently long period to be considered representative.

It was, therefore, necessary to estimate the maintenance cost for alternating current motors from the records of the direct current motors. It was assumed that the care and inspection would be equal for the two classes. The delays and repairs for the direct current motors were segregated as follows: (1) Commutator troubles and repairs directly or indirectly due to same. (2) Brush-holder troubles and repairs directly or indirectly due to same. (3) Bearing troubles and repairs directly or indirectly due to same. (4) All other troubles and repairs.

It was assumed that for alternating current motors all commutator troubles and repairs would be eliminated, all bearing troubles and repairs doubled, and all other troubles and repairs remain the same as for direct current motors. Figuring on this basis, it was found that there would be an annual saving in favour of alternating current motors, as follows:—

Repairs ....£3. 3s. per motor.
Delays ....3·4 minutes per motor.

Applying these figures to the particular case in consideration showed an annual saving in repairs of 182 × £3. 3s. = £573, and an annual saving in delays of 182 × 3·4 = 619 minutes. As the average output of the various mills would be about 1·5 tons per minute, the saving in output resulting from alternating current motors would be 619 × 1·5 = 929 tons annually. This saving in output has, of course, a real value; but as both the tonnage and value of same vary so much in different cases and are hard to arrive at in any case, no effort has been made to capitalise it.

The difference in power requirements between the two systems was so small that there could not conceivably be any difference in the size of engines or gas handling plant, and the only amount properly chargeable to the difference in power is that due to the actual difference in gas used. On the basis of 300 working days per year, of 20 hours each, valuing gas in the standard manner and considering the actual efficiency of the engines it was found that the fuel cost of power at the engine shaft amounted to 24s. per kilowatt-year. Figuring on the various items of annual costs with the methods outlined above, it was found that there would be a net saving of £430 per year in favour of the all-alternating current system.

No spares have been figured for the sub-station equipments. In case a spare unit is considered desirable it would add considerably to the cost of the mixed system, as one motor-generator set would cost much more than one transformer. In the sub-station equipments there would undoubtedly be more expense for maintenance and repairs on the motor-generator sets than on the transformers, so that the mixed system ought properly to be charged something for this difference. It would not, however, be a very large amount and has not been included. No figures have been included for attendance for the motor-generator sets. In the case considered the sub-station apparatus would be located in the same rooms with the large motors, so that no additional attendants would be necessary with the mixed system. This would usually be the case, although in some instances it might be that the mixed system should be charged an additional amount for this item. It is reasonable to suppose that there would be more shutdowns with the mixed system due to the sub-station equipments, as motor-generator sets are naturally more subject to trouble than static transformers. This amount would probably not be large, and no effort has been made to capitalise it.

In estimating the cost of power the minimum possible amount, viz., the cost of fuel alone, has been considered. To be absolutely accurate it should be considered that any difference in power between the two systems would cause a corresponding difference in first cost of engines, boilers, or gas cleaning plant, &c., also in the operating cost as regards lubricants, attendance, repairs and maintenance. The value of all these would depend upon the relative proportions between the total power required for the plant under consideration and the total capacity of the power plant. For instance, if, in the case considered, the power station furnished power for this one installation alone, the small difference in the total amount of power required by the two systems would probably make no difference in the first cost of the power station, nor would there likely be any difference in the total operating expense of the station. If, however, the power plant furnished considerable power in addition to the requirements of this installation, these items would have to be considered, because any difference in capacity due to the difference in power requirements of the two systems becomes available for supplying the additional load. A study of 16 cases would indicate the following:

1. The alternating current system costs slightly more than the mixed system. (a) Excess first cost higher for 22,000 volts transmission than for 6,600. (b) Excess first cost higher for gas engines than for turbines. From this it appears that the higher the first cost of power supply the less favourable is the use of the all-alternating current system.

2. The lower the power-factor the greater is the excess cost of the all-alternating current system for both percentages of auxiliary load.

3. The less the percentage of auxiliary load the less the excess cost of the all-alternating current system for both power-factors.

4. The annual costs of the all-alternating current system considered are lower than those of the mixed system.

5. The actual operating costs, excluding interest, depreciation, taxes and insurance, of the all-alternating current system are considerably less than those of the mixed system.

6. The excess cost of maintenance of the mixed system is based on an estimate and not on actual records. Should this item be entirely neglected, the results in nine out of sixteen cases would show an excess of annual costs for the all-alternating current system, but the amount is so small that accurate calculations for any individual case would be necessary to determine the relative advantages.

7. When the saving in output, due to the reduced delays, in the all-alternating current system is taken into consideration the saving in annual costs, as tabulated, will be largely increased; and even should the difference in motor maintenance be neglected there would still be a considerable saving in annual costs for the all-alternating current system.

In conclusion, then, for a rolling mill properly motored, where the percentage of power required for auxiliary apparatus (exclusive of pumps, &c.) is 25 per cent. or less of the total power delivered to that mill, and where the power-factor of the entire mill, including both main and auxiliary apparatus, is 70 per cent. or over, the authors feel amply justified in saying that the all-alternating system will show a saving in annual cost, to say nothing of its greater simplicity and more satisfactory operation.

YIELD POINT IN METALS.

A REVIEW of some of the recent work upon the yielding of metals under stress was presented by Mr. W. Mason, in the course of a paper entitled "The Phenomenon of Yield Point in Metals under Stress," read at a recent meeting of the Liverpool Engineering Society. He said that regarded from a general standpoint, the objects of strength-testing were two—viz., comparison of quality and determination of the physical properties of materials. He was concerned with only one aspect of the second of the objects, for he had little to do with the important metallurgical aspect. He believed that investigations of the physical properties would have a large practical bearing besides their scientific value. That rather chaotic function called the factor of safety, and that more respectable mixture of experience, ignorance and rule of thumb, called the working stress, did not give satisfaction to the engineer who wished to design rationally and economically. Investigation of the uncertainties, large or small, that swelled the dimensions of the factor of safety, or were neatly hidden under a multitude of working stresses, must tend to better and more economical design, and he referred particularly to the uncertainties, both of material and stress, which were involved in questions of impact. With a more extended knowledge of materials and a more intimate understanding of the incidence and absorption of impulsive energy, why should there not be established, even in the most uncertain and difficult of conditions, more rational and, in many cases, quantitative bases of design?

COMPRESSED AIR AS A FOUNDRY AUXILIARY.*

BY WILLIAM H. ARMSTRONG.

THE first and most important factor in a compressed air installation is the air compressor. The average jobbing foundry requires a compressor of 300 cub. ft. to 500 cub. ft. piston displacement. Large foundries may use up to 1,500 cub. ft. or 2,500 cub. ft. Novelty foundries usually require small machines of 50 cub. ft. to 100 cub. ft. displacement. Great care should be exercised in the selection of the compressor, as all the working apparatus and final results rest on the character of the machine installed. There are no general conditions which will apply equally in all cases, each installation requires careful individual consideration. The most economical power available generally determines the type of compressor, that is, whether belt drive from line shaft or from electric motor, direct drive from motor rotor, or direct steam drive. Price should not be considered to much as service.

The foundry compressor should be as nearly dirt proof as possible and as nearly automatic in its operation as it can be made. Machines that would give perfect satisfaction when operated in connection with a power plant and in charge of skilled engineers frequently go to pieces when installed in a foundry where skilled mechanics are not so readily available, where the machine has to take care of itself, and where dirt and dust abound. These remarks refer not so much to the large foundry which maintains a good size power plant, either for itself or jointly with other departments of the works, as to the independent jobbing foundry which produces such a large percentage of our total foundry product.

The value of the pneumatic chipping hammer in a foundry, as a saver of time and labour, is so universally conceded that the time has passed when it is deemed necessary to submit comparative figures, especially as much depends upon the conditions of operation and efficiency of the air plant. But suffice it to say that for all classes of chipping in foundry work, such as chipping fins off castings, cutting gates, risers, buttons off anchors, and general trimming, one man with one hammer of the proper size will do as much work as three or four men chipping by hand. These tools are made in different sizes, with piston strokes of 1in. to 5in., to meet different conditions. It is important that the proper size tool should be selected for the work, to ensure the best results, the short stroke tools being intended for the lighter work, requiring a light and very rapid blow, the longer stroke tools for the heavier work, requiring a heavy and slower blow. The medium sizes, with 2in. and 3in. piston stroke, are the sizes most generally used for foundry work.

The rotating air drill is another very familiar labour-saving device, though its field of usefulness in a foundry is somewhat limited. It is more particularly a general shop tool, possessing a very wide range for drilling, reaming, tapping, flue rolling, running in stay bolts, studs, and other applications seemingly limitless. It has established itself next to the pneumatic hammer as a most generally used air tool.

In portable air tools the sand rammer is unquestionably the next in importance to the chipping hammer, as applied to foundry work, and due to the marked improvements that have been made in the construction of this device, which tend to lessen the shock on the operator, and the education of the operators in the proper way to handle them, it has made a permanent place for itself, even against strong opposition, on the grounds of economy, lower production cost, larger output and improved quality of product which follow its use, and the adoption has become more general.

The pneumatic rammer does much more than merely to supply the power for the work. It also changes the character of the ramming and gives the operator a variety of execution in the ramming which his muscles, at the best, could not command. The force, the direction, and especially the rapidity of the blows are so completely under the control of the operator that we might compare the manipulation of the rammer to the playing of a musical instrument. It relieves the moulder of the most fatiguing detail of his work.

In discussing recently the question of pneumatic sand rammers with the superintendent of one of the best organised and most representative foundries in this country, he made the following comments: "The pneumatic sand rammer for foundry work has demonstrated that it is one of the greatest friends and labour savers of the progressive foundryman to-day. When the sand rammer was first introduced, there was some criticism concerning it, mainly arising from the natural antipathy mechanics had for anything in the machine line, but as the operators became familiar with its use and recognised its effectiveness, this feeling rapidly disappeared. To-day in our foundry the men take kindly to these rammers, and use them entirely for work of every description. Some writers claim that while sand rammers are valuable for ramming drags, they cannot be used successfully on copes. We have exploded this contention completely in our shop and use the rammers on both copes and drags indiscriminately and with equal success.

"The sand rammer is often put up against the jarring machine, and many claim that with the introduction of jolt machines the efficiency of the sand rammer is materially diminished. We have not found this to be the case. For medium size work that is made in quantities, we believe the jolt machine to be indispensable; even with this, however, the rammer is a very important factor in butting off the tops of the jolt-rammed moulds. When larger patterns are rammed, such as engine beds, sole plates, sub-bases, &c. it has been our experience that the sand rammer is equal, if not superior, to the jolt machine. This statement is made upon taking into consideration the expense and labour incident to rigging up a pattern for use on a jolt machine, the tendency the mould has to sag upon being rolled over, the bolting on the plates before rolling the drag, and such other details as are encountered in rolling over a large job. On the other hand, if the pattern is bedded in the ground or flask and rammed up with pneumatic rammers, which may be done with unskilled help, much of the expense and delay is eliminated, while we are sure of a perfectly true job, conforming to every detail of the pattern.

"The pneumatic bench rammer is a very handy tool as an auxiliary to the larger rammer. This rammer is very satisfactory for ramming under a shelving pattern where the construction of the pattern is such that it is difficult to ram under it with the larger tool. We find the bench rammer practically indispensable for work of this nature. Speaking generally, it is my opinion that the sand rammer has increased our efficiency in this line fully four or five times, and since we have had them installed we would regret very much to be obliged to go back to the old way of ramming."

The air hoist is valuable in conveying flasks outside of foundry to storage sheds, patterns to pattern shop, or finished castings to machine shop; also for lifting flasks and copes, drawing patterns, conveying cores to ovens, for operating cupola elevators and core oven doors. The most common types of air hoists are simple cylinder hoists, either vertical or horizontal, although the motor geared type of hoist is being very largely adopted for heavy travelling on jib cranes. Either of these types may, in many instances, be applied to hand power cranes already in use, without in the least interfering with the gearing, and at very small expense. In the air hoist the power and load are brought together in the most simple manner. A boy, with this aid, can lift a given load a dozen times, while a gang of several men would be operating a chain block or windlass. There is practically no noise, no jar, and the load is always balanced. In foundries where an overhead traveller cannot be installed, air hoists, suspended from trolleys running on a track, are very satisfactory. Few realise how cheap an air hoist is to operate apart from its convenience and speed in handling loads. It has been estimated by Frank Richards, a well-known writer on compressed air subjects, that at 100lbs. gauge pressure compressed air costs 2½d. per 1,000 cub. ft. of free air.

The moulding machine has also taken a very prominent place among foundry labour-saving devices, enabling increased output and a higher grade of product. At first, there was considerable opposition on the part of skilled moulders to the adoption of this machine, and it was looked upon as a foundry luxury. It is now looked upon as a foundry necessity. The moulding machine is equally well operated by highly-skilled workmen or by the ordinary labourer. The economy required of foundry managers in all lines of work makes imperative the introduction of some type of moulding machine. Practically every line of castings can

* Abstract of paper read before the Newark Foundrymen's Association.

now be successfully and economically moulded on either power or hand machines. The range has been broadened to meet every modern condition of foundry practice; and the installation of the moulding machine is now merely a question of type and local conditions. The degree of efficiency obtainable is a matter of personality, and the right machine. These machines are operated by compressed air at a pressure of 60lbs. to 80lbs.

There is hardly an operation in a foundry of greater importance, and which contributes more to a satisfactory factory product, than the proper and thorough cleaning of castings. It has been an operation requiring time and patience, and involving heavy expense. The cleaning of castings is a subject that has been given unusual attention, being followed by experiments with various and sundry methods and devices for the successful and economical accomplishment of the desired results, including brushing, tumbling, pickling, blowing, &c. These methods have each shown marked advantages as applied to particular classes of work, but as a commercial proposition for all classes of castings, large, medium, and small, steel, iron, aluminium, and brass, the solution has been found in the sand blast, and here again, compressed air plays a most important part and shows its superiority over other actuating powers for general foundry work.

The sand blast, however, is by no means a late development, but it is only within recent years that it has been perfected to a stage where it produces satisfactory results, as applied to both external and internal surfaces, and also to crevices, and combines economy in power, that is, in the consumption of compressed air, with effective savings in both time and labour, and a resultant total economy.

There are many makes, styles, and kinds of sand blast apparatus on the market, and superior points are claimed by the manufacturers for each, some advocating the use of air under high pressure, and others under low pressure. The proper air pressure for sand blasting as applied to particular classes of work, has been the subject of much discussion among foundrymen and also sand blast manufacturers, and numerous theories have been expressed through the trade journals. There have also been a number of tests conducted on different classes of work, with varying air pressures, and the consensus of opinion as expressed in the reports of these various tests, at least so many of them as it has been the writer's privilege to read, seems to favour the high-pressure blast for all classes of work. It is conceded that the volume of air required is governed by the size of the opening in the sand blast nozzle, and the pressure maintained, based on the standard flow of air at a given pressure through a given size orifice. Therefore, the higher the pressure, the greater the volume of air used, but the amount and quality of work done increases correspondingly without added labour costs. It has been proved in these tests that twice as much work can be done at 50lbs. pressure as at 20lbs., at 64lbs. as at 30lbs., and at 72lbs. as at 40lbs. It has also been shown that for grey iron and malleable castings they can be cleaned best and quickest with an air pressure of 80lbs., brass and aluminium castings at not lower than 60lbs., while for steel castings, the hardest to clean, not less than 90lbs. The character of the material and its ability to withstand the impact of the sand will determine the pressure adaptable.

The sand blast may be used in connection with tumbling barrels. In a test on one of these machines 360lbs. of brass castings were put into the barrel just as they came from the mould and the time was 15 minutes, which included the time to load, clean, and unload the barrel. An average maintained on this run was 70lbs. and the abrasive used was No. 40 Angular grit, through ¼in. nozzle. In a paper read by Prof. William T. Magruder, Professor of Mechanical Engineering in the Ohio State University, at Columbus, Ohio, before the American Society of Mechanical Engineers at the annual meeting in 1911, he pointed out that as shown by tests conducted by him the greatest efficiency for sand blasting is obtained by having the nozzles at the right distance and correct angle for the work.

The air torch has been found a great time and labour saver for skin drying copes, moulds, &c., heating ladles, lighting cupolas, and repairing castings. An air nozzle designed for blowing blacking on moulds, cores, &c., consists of a T, made of about ½in. pipe, with discharge end bushed to about ¼in. The air is connected so as to cross the top of the T. A short section of hose is connected to the bottom or stem of the T, which goes to the receptacle holding the blacking. As the air is blown through the top of the T it siphons the blacking and blows it in a spray over the work, reaching and covering every corner or crevice.

THE NEXT IMPROVEMENT IN STEEL MAKING.

By George Auchy.

Mould-killed steel is in a sense the final improvement in steel making—the logical and inevitable culmination of all improvements; that is to say, no improvements in steel making, chemical or mechanical, with mould killing left out will make a steel as good as steel can be made. By mould killing the writer means holding the steel quietly fluid for a time in the moulds (basic lined) by the heat of electric arcs in the covers the moulds are provided with.

It is very generally agreed that the superiority of crucible steel is due to the killing. Impurities, solid and gaseous, have a chance to escape that is lacking in the Bessemer and open-hearth processes.

Killing in Crucibles has Shortcomings.—But although killing in crucibles is far better than not killing at all, it yet falls considerably short of what it might be. For the good effect of the killing is to a certain extent undone by the teeming into the moulds afterwards. The separated slag and oxide are to a certain extent mixed up again with the steel. Fresh slag and oxide are to a certain extent formed by the exposure to the air in teeming. Air is to a certain extent carried along in by the falling stream. Fresh volumes of gases are to a certain extent evolved at the lower temperatures just before solidification.

Moreover the rapid chilling causes a segregation of chemical impurities all around the ingot about one-fourth the distance to the centre; traps a pocket of segregated impurities in the middle upper half of the ingot that would in all probability have risen clear to the top, given time enough; and last, but not least, causes a pipe to form that could not have formed had the solidification been gradual, and that of the top last of all.

Obviously the crucible is not the place to do the killing. Obviously the mould is the place to do the killing. But obviously again, if this is done there is no further occasion for the use of crucibles, and they can peacefully pass out of practice, and the steel be made economically in large masses Bessemer or open hearth way, and the mould-killed product excel in quality present day crucible killed steel.

Chemical Purity Persistently Sought. — However this may be, it is absolutely certain that the steel must be mould killed to be the best possible steel. This would seem plain. Then why has the steel maker been slow to see that mould killing has been for some time a practical proposition? From the view that it is as a matter of fact not a practical proposition, and exists only in the lively imagination of the writer, that individual would stoutly dissent. He would attribute the indifference of the steel maker heretofore to this improvement to the fact that, although the latter has always clearly recognised the importance of sound clean ingots, he has considered chemical purity as of vastly more importance still, and it has therefore been along this latter line that his efforts have been concentrated. This was natural and indeed inevitable. Output and not quality has been so far the steel maker's main aim (although not his only one—for he has been anxious for quality also), and he is, therefore, strongly disposed to favour a recipe for making steel good that does not interfere with that aim, and to put off until the last moment the consideration of one that does so interfere. This being the case, it was inevitable that when the chemical engineer years back gave him the assurance that although there was something in making steel carefully, and although there was something in treating it right, yet getting it strictly "C. P.," or as near to that as possible, was the main thing to ensure good quality, he should jump at it joyously and assimilate it eagerly. And so he has resolutely and ruthlessly been chasing the last hundredth of phosphorus out of his steel, and at the same time has pushed his output with undiminished ardour and success.

Chemical Composition an Exaggerated Factor.—But the ultimate result has not been entirely satisfying. The chemically pure and mechanically impure steel has turned out to be on the whole no better than it should be, and at times fatally and disastrously disappointing, and the steel maker is being forced to a realisation of the distasteful truth he has so long pushed to the background. That truth is that although within wide limits chemical composition is everything, and both soundness and heat treatment as nothing, in determining the properties and the quality of steel, yet within comparatively narrow limits (really pretty wide) the reverse of this holds good, and it is chemical composition that is as nothing, and soundness and heat treatment everything. Taking a piece of tank steel, a piece of tool steel, and a piece of high-speed tool steel, we see at once that the enormous difference in the properties of these three steels is due entirely to differences in chemical composition. No degree of mechanical purity and no amount of heat treatment will make a tool out of the first or a red-hard tool out of the second, and the chemical engineer's proposition obviously has a solid foundation of indisputable truth to rest upon. But now to go further, and compare high-speed steels with high-speed steels, and carbon tool steels with carbon tool steels, for the chemical engineer to impute the great differences in quality that occur in practice to small differences in chemical composition is to go too far. It is working nature's laws to death. It is seeking a significance where there is no significance.

Same Analysis but Different Physical Properties.—Where is the proof of this last assertion that within comparatively narrow limits chemical composition is of no importance? The proof is ample and convincing. It is to be found in the experiments of Taylor and in the experiments of every investigator. The same chemical composition gives widely different results, and widely different chemical compositions give the same results. The proof is, moreover, to be found in the daily experience of every practical steel man. He sees good steels chemically give poor results in service, and poor steels chemically give good results in service. A steel goes wrong. An analysis is promptly made. Almost invariably the comment is, "Well, the analysis is all right." Again, a steel rail that has stood 35 years of service is taken up to see what a good rail analyses. It analyses bad, and would have been rejected under modern chemical specifications. Yet it stood, while the modern rail, meeting every specification promptly, "lies down and quits." It would really seem as though a possible way of making modern rail specifications of some value practically would be to reject the rails that meet the chemical specifications and accept those that do not.

In short, all experiment and all experience go to show that the pleasing theory of the chemical engineers—the theory that if a steel be pure chemically, nothing else matters much—is not true. Not only that, but it is perhaps the exact reverse of the truth. Just as in the paint trade it is developing that the purer a paint the poorer, so in the iron trade is sentiment veering with regard to the chemically combined and alloyed impurities in steel. Elements that like copper were formerly carefully kept out are now frequently carefully put in, and elements like silicon that a few years ago could not be got low enough, now cannot be got high enough to suit many. It might not be a wild guess that in the near future phosphorus will be specified for instead of against, and sulphur accepted with equanimity and allowed to shift for itself. In mould killed steel it would probably find its way, although leisurely, to the slag as sulphide of manganese. And the superiority of alloy steels is beyond question.

The fact is that the chemical engineer's extreme theory would long since have been abandoned had it not been for some powerful motive to the contrary. That motive in a word is output, and is a motive potent enough to cause the steel maker to stick to the theory to the last ditch. But it would seem that the last ditch has at length been reached. The steel maker can no longer compel himself to ignore obviously and constantly recurring facts, and can no longer put off the consideration of true theories. Not so triumphantly does he still wave his chemist's report aloft as a guarantee of quality, and more and more every day we hear of "slag inclosures," "occluded gases," "pipes," "blowholes," "segregations" and "discards." "The Iron Age" in a recent editorial said: "Increasing emphasis has been put of late in the voluminous discussions on rail steel on the imperative necessity of finding a way to prevent the unsoundness which enters into steel in the very process of casting and solidification into its original form."

With the iron trade thus in earnest and on the right scent at last, it will not take long for a general realisation of the fact that the one sure, scientific and only way of making sound, clean, reliable steel is to kill the steel in the moulds by overhead electric heat, solidifying the top of the ingot last; provided, of course, there are no lurking and insuperable mechanical difficulties, and that the cost is not too great. With regard to the first point, the writer for his part can see no probability of great trouble. With regard to the second point it would seem plain that if it does not cost too much to refine open hearth steel in an electric auxiliary furnace, it would cost considerably less to kill it electrically in the moulds instead of thus refining it further in an auxiliary electric furnace. Here the point must be raised that if the writer's idea of the utter inutility of extreme chemical purity be correct, then the trade in using electricity to refine steel to a greater degree than it can be refined in the ordinary open hearth furnace is entirely on the wrong track, any gain in quality thereby to the contrary notwithstanding. For such gain would seem to be due to less impurity mechanically held rather than to less impurity chemically combined, and this consummation can, of course, be far better reached by killing in the moulds, omitting the supererogatory (and it might be added superstitious) step of refining in the electric auxiliary furnace. Clearly, the chemical engineers are half right, and just as clearly they are half wrong. Within very wide limits of chemical composition it is true the analysis tells everything. But within narrow limits it tells nothing—there is nothing to tell—and all metallurgical efforts based on the reverse of this latter proposition can accomplish nothing except the familiar achievements of good money resolved into its original elements.—"The Iron Age."

ACCIDENTS TO MONOPLANES.

The report has been issued of the Committee appointed by the Secretary for War to enquire into the causes of recent accidents to monoplanes of the Royal Flying Corps. The specific fatal accidents into which the committee enquired were those in which Captain Hamilton and Lieut. Wyness Stuart were killed at Gravely, near Hitchin, and Lieut. Hotchkiss and Lieut. Bettington, who lost their lives at Walvercote, near Oxford last September. The committee also investigated the accident in the same month to Major Gerrard, which fortunately was not attended with serious consequences to the flier. The first disaster, they believe, probably arose from some damage to the engine or its mounting or to the propellor. The Oxford accident probably resulted from the breaking of a tubular ferrule intended to secure the quick release attachment on the right wing cable, and Major Gerrard's mishap was due to fracture of a gudgeon pin and a connecting rod in the engine. In their conclusions the committee say that as regards that enquiry they had no information before them which would lead them to conclude that the monoplane, as such, is less stable than the biplane, and that the accidents to the monoplanes specially investigated were not due to causes dependent on the class of machine to which they occurred, nor to conditions singular to the monoplane as such. After consideration of the general questions affecting the relative security of monoplanes and biplanes, the committee found no reason to recommend the prohibition of the use of monoplanes, provided that certain precautions are taken, some of which are applicable to both classes of aeroplanes. They make various suggestions for strengthening machines, the examination and testing of machines, regular inspection of all machines, the engagement of two or three skilled mechanics for each squadron as instructors, and to set a standard of technical workmanship.

NICKEL AND NICKEL ALLOYS.

An interesting lecture on "Nickel and Nickel Alloys," was delivered by Mr. G. A. Boëddicker, of Birmingham, at a meeting of the Sheffield Society of Applied Metallurgy held on Monday last. The lecturer showed that great advances in the production of nickel had taken place since 1875, up to which time no method existed for the separation of nickel from copper by a metallurgical process. Such a process was discovered by Thompson, of New York, and this made available the enormous deposits of nickel-copper-sulphide ores in the Sudbury district of Canada. This process was so successful that at present about two-thirds of the world's production, which had risen to 24,000 tons per annum, was produced in Canada. The great increase in consumption was largely due to the use of nickel in nickel steel, which contained up to 30 per cent. of nickel. The discovery of Dr. Langer, that nickel could be volatilised by carbon monoxide, and so separated from copper, had given a further process for the manufacture of pure nickel from copper ores. Binary alloys of nickel and copper, ranging from 15 to 40 per cent. nickel, were used for coinage metal and resistances. The copper, nickel, zinc alloys known under the name of German or nickel silver, had a great variety of compositions. The action of nickel was a whitening of the colour and the raising of the electrical resistance. In both these qualities nickel was entirely different from cobalt, which had very little colouring effect, and raised the resistance very slightly. The use of chloride solutions was generally preferable for the electrolytic determination of nickel, as it worked quicker and easier. The presence of a small quantity of zinc in the nickel prevented the complete deposition of the nickel with an ordinary current of, say, 1 ampere. The lecturer mentioned that cobalt was being largely used in the making of a new high-speed tool steel. The supply of cobalt ores came from Cobalt, Ontario. The quantities in sight were undoubtedly large, but the quantities of payable ore at present prices were limited, and could not possibly be put at more than 750 tons per annum. Of this, about 300 to 400 tons were required for cobalt oxide, leaving about 300 tons disposable for the manufacture of metal. This was a very small quantity. At one works in Germany, where high-speed cobalt tool steel was being made, already over 100 tons per annum were consumed. As the price of cobalt at present was £600 per ton, this represented £60,000, so that the manufacture of cobalt steel must already be very considerable. If cobalt steel came into extensive use, and it became necessary to increase the production of cobalt, poorer ores would have to be worked up, and a considerable rise in price would result.

CABLES FOR MINE SHAFTS.

This subject was dealt with by Mr. E. Kilburn Scott, in a paper recently presented before the Association of Mining Electrical Engineers. He pointed out that cables for shafts of mines differed from those in other situations because the question of weight was so important a factor. In order to reduce the weight the cables should be worked at high tension and insulated accordingly. Although aluminium had not been used for shaft cables there was every reason to suppose that the lighter metal would be found distinctly advantageous. Contrary to the general supposition, it was much stronger from the point of view of supporting its own weight than was copper. All metal work which was continuous from the top to the bottom of a shaft should be utilised as the earth return. There was nothing in the Revised Rules against this being done, or indeed requiring shaft cables to be armoured. In any event the cross section of the armour of a high tension cable was likely to be too small to earth properly the low tension underground feeders. Even where it was not convenient to use existing metal work it would be much cheaper to suspend wire ropes in the shaft for the earth return than to place the same amount of metal round a cable as armour. He pointed out the marked success which had followed the use of silicious tyre rubber as a mechanical protection on cables subjected to moisture and hard wear and tear, and was of opinion that it was also a very suitable material for cables permanently installed in shafts. Hitherto casing had always been made of sawn planks, the joints of which were difficult to keep tight. The use of telegraph poles sawn longitudinally and having the joints between the halves closed by steel hoops was suggested. Casing made in that way should be cheap and easy to erect, and it would form a complete protection to the enclosed cable. As regards preservatives for casing and cleats saccharine impregnated into the wood had no action on insulations or metals; also when impregnated along with arsenic it was a solution of the white ant difficulty which was so troublesome in mining work oversea.

INDUSTRIAL AND TRADE NOTES.

Diesel Engines.—An order for five Diesel engines of 1,000 b.h.p. each, for the Mersey Docks and Harbour Board, is being carried out by the Consolidated Diesel Engine Manufacturers, Ltd., who obtained it after severe competition. The manufacture of the engines is in the hands of the Usines Carels Frères.

Underground Electric Railway for Sydney.—The New South Wales Cabinet has approved a project for the construction of electric underground railways in Sydney, the city section of which is to consist of three lines instead of two, as originally recommended. Preparations are being made for beginning the work immediately the project is sanctioned by Parliament.

Large Electric Crane for Belfast. — The Belfast Harbour Board have, we learn, accepted the tender of Messrs. George Russell and Co., Ltd., Motherwell, for the construction at Alexandra Wharf of an electric derrick crane capable of lifting 120 tons, the price being £8,725. Additional expenditure of £1,300 will be incurred for the foundations and other necessary work.

Hydro-Electric Power Scheme in Prussia. — A Bill has been laid before the Prussian Diet, for the development of water power on the upper waters of the Weser. The Bill provides for an expenditure of £442,500, of which it is proposed to spend immediately £245,834 on the erection of power stations at Hemfurt and Helminghausen; the remainder will subsequently be spent on the construction of a power station at Münden. It is estimated that the three stations can produce 41 million kilowatt hours annually.

Electrically-driven Rolling Mill for Non-ferrous Metals. — The Birmingham Battery and Metal Company, Ltd., have adopted in their works at Selly Oak an electrically-driven reversing rolling mill, operated on the Siemens-Ilgner system, for the rolling of non-ferrous metals. The rolls are 18in. and 21in. diam., and are capable of rolling sheets weighing 1·1 tons. The driving motor works at 1,270 revs. per minute on direct current, at 440 volts, generated by dynamos driven by gas engines. The flywheel weighs 3 tons.

Russian Petroleum Production.—According to figures recently published, the production of petroleum in Russia showed a slight increase in 1912, as compared with the previous year. During 1912 the production was 8,960 tons. During the past decade there has been an almost constant decline in the output of petroleum in the old established fields of Baku, whilst the output in the comparatively new districts has increased. It would seem, therefore, that the future of this industry lies in the possibility of opening up and developing new petroleum wells.

The Malay Dreadnought.—The contract for the Dreadnought to be presented to this country by the Federated Malay States has been placed by the Admiralty with Messrs. Armstrong, Whitworth, and Co. The battle-ship will cost about £2,250,000, and will inaugurate Messrs. Armstrong, Whitworth's new naval works at Walker, which are now almost ready for occupation. The vessel will be called "Malaya." There are at the new shipyard nine building berths, of the following lengths: 1,000ft., 900ft., 800ft., 650ft., 550ft., 500ft., 450ft., 400ft., and 350ft. The equipment will be of the most modern kind, and the works, when in full swing, will rank among the finest of their kind in the world.

London and South-western Railway: Electrification Proposals. — Presiding at the recent half-yearly meeting of the London and South-western Railway, Mr. Hugh W. Drummond, in referring to the question of electrification, said they had gone into the matter, and were fully prepared to go on with it almost immediately. The complete programme put before them was to deal with the lines from Waterloo to Hounslow, Shepperton, Kingston, and Hampton Court on the north side, and as far as Guildford on the south side of the main line. But for the present they only proposed to go in for the line on the north side, including the electrification of the main line as far as Hampton Court Junction.

The Pay of Dockyard Electrical Engineers.—The Admiralty has decided that in future electrical engineers and assistant electrical engineers serving in the Royal dockyards will be paid the following pensionable scales of salary in place of the non-pensionable salaries now payable: Electrical engineers (higher grade), £450, rising by annual increments of £20 to £650, with an official residence or an allowance of £50 or £75 in lieu; electrical engineers (lower grade), £300, rising by annual increments of £15 to £400, with an official residence or an allowance of £50 in lieu; first assistant electrical engineers, £250, rising by annual increments of £10 to £350; second assistant electrical engineers, £200, rising by annual increments of £10 to £250.

Municipal Trading. — In connection with the Sheffield Corporation Bill, an important sub-clause to clause 98, in lieu of sub-clause 2, was agreed to in the House of Lords on the 4th inst. to the effect that: "The Corporation may enter into contracts for the execution of any of the powers of this section, including the wiring of private property. The Corporation shall not under the

powers of this section sell any such electrical fittings (other than electric lines, fuses, switches, ceiling roses, and such other electrical fittings as are used in connection with the wiring of private property from the distribution main as far as the ceiling, wall, or floor outlet only) except through a contractor carrying on his business independently of the Corporation."

Mexican Petroleum Production.—The production of crude petroleum in Mexico in 1912 is estimated at 20,000,000 barrels, and this quantity, it is stated, could easily have been increased had the storage and marketing facilities been more adequate. During the first nine months of the year, 1,237,000 barrels were exported to the United States. Besides the pipe lines under construction, and being planned, for the delivery of oil to Tampico, Tuxpam, and Vera Cruz, with one, or possibly two, lines running to Texas, much attention is being given to providing fleets of oil tank vessels. Pending the building of these vessels, tank farms are being constructed for the storage of the large quantities of oil that cannot be put on the market owing to the impossibility of chartering oil vessels.

Pig-iron Production in Manchuria.—The Chinese Colliery and Iron Mine Company in Manchuria, has, we understand, decided to work the Pengchihu colliery and iron mine on a large scale, and establish an iron foundry there. The company will use the greater portion of its own coal for its iron foundry undertaking, and dispose of the rest in the form of briquettes. It is anticipated that 100 tons of pig iron can be produced daily with the plant to be laid down. The operations of the iron foundry will be opened with one smelting furnace, which is capable of producing 100 tons a day. Japan, which has only small supplies of iron ore, has to import about 40,000 tons a year, and the opening of the iron foundry business at Pengchihu is expected to affect the pig-iron market in that country.

Labour Co-partnership.—Mr. Thomas Burt, M.P., in his monthly circular to the Northumberland Miners' Association, refers to the subject of labour co-partnership. He states that, personally, he has always looked hopefully towards some form of co-operation or co-partnership to initiate a better industrial system than that which now prevails. No great change can come suddenly or without preparation, and the workmen themselves must take a large part in bringing about any reform of a permanent kind. But when fair-minded, liberal employers are ready to co-operate, their assistance should be welcomed without nagging and suspicion. Though co-partnership may not prove a complete and final solution of the problem, it will be of enormous educational value, and it will prepare the way for a better system.

World's Output of Iron Ore, Pig Iron, and Steel.—According to a return recently issued by the Board of Trade, the world's output of iron ore in 1911 was about 145 million tons; the figures so far available indicate that the output was less than in 1910, owing chiefly to a reduction in the output in the United States of about 15,900,000 tons. The principal producers of iron ore are the United States, Germany, the United Kingdom, France, and Spain, in the order given, these five countries producing about six-sevenths of the total output of the world. The total quantity of pig iron produced in the world in 1911 may be estimated at about 63 million tons. The principal countries of production are the United States, Germany, and the United Kingdom, in the order named, these three countries together accounting for about seven-ninths of the total output of the world. The combined output of steel in the United Kingdom, Germany, and the United States in 1911 exceeded 45 million tons, and the world's output may be estimated at between 59 and 60 million tons.

Employment in German Engineering Trades in 1912.—An interesting report on employment in Germany, issued by the Imperial Statistical Office at Berlin, shows that during 1912 the country enjoyed a fair share of the rising wave of industrial prosperity. Returns indicating increased activity were received from the majority of trades, and the improved state of the labour market which had been experienced in 1911 continued during the past year. As regards coal-mining, the total output of coal in 1912 amounted to 259·4 million tons, and exceeded the aggregate for 1911 by 25·2 millions. Blast-furnaces were well employed throughout the year, and at times were very busy. The total production of pig-iron in 1912 reached the record figure of 17·85 million tons, as compared with 15·55 millions in 1911—an increase of nearly 15 per cent. in two consecutive years. Iron foundries were also busy, but suffered from a dearth of skilled workers. Tube works, steel works, and rolling mills all furnished reports indicating good employment. In the general engineering trades employment was satisfactory, according to the large majority of the reports. The electrical trades were busy right through the year, orders being received in increasing quantities, and employment was better than in 1911.

Canadian Trade Disputes Act.—A White Paper has been issued giving the report to the Board of Trade of Sir George Askwith, Chief Industrial Commissioner, on the working of the Industrial Disputes Investigation Act, of Canada (1907). Acting on the instructions of the British Government, Sir George toured Canada in September and October last year, and examined from the British point of view, its usefulness as a means of averting or settling disputes, with the object of considering how far any development on the lines of the Act could be of service in this country. The main features of the Act are that it requires any dispute arising in connection with mining, the transportation industry, or public services to be submitted to a Board of Conciliation and Investigation with a view to effecting a settlement before a strike or lock out can be legally declared, and stipulates for at least 30 days' notice of any change affecting conditions of employment, and that pending proceedings before the Board in the event of such change resulting in a dispute neither party shall precipitate matters on the pain of penalties. Sir George points out that the Act differs essentially from compulsory arbitration, and merely legalises the community's right through a Government department to intervene before stoppage, with a view to securing adjustment by discussion and negotiation. He thinks what objections there are can be remedied by amendment, without altering the main principles of the Act. As regards its adaptation to this country, Sir George arrives at the conclusion that the real value of the Act does not lie in compulsory restriction, with attendant penalties upon the right of proclaiming a strike or lock out, but rather in the forwarding of the spirit and intent of conciliation, and that an Act on the lines of conciliating parties, and of making recommendations where conciliation was unavailing (even omitting restrictive features aiming at delaying stoppage until after enquiry) would be suitable and practicable in this country. Such an Act, while not ensuring complete absence of strikes and lock outs, would, he thinks, be valuable alike to the country and to employers and employed.

Fire Prevention Precautions at the Ghent Exhibition.—The mention of an international exhibition cannot fail to suggest the danger of fire ever since the terrible disaster which befell the Brussels Exhibition of 1910, when, in a matter of minutes, besides other buildings, the British and Belgian industrial sections, with their priceless contents, were entirely destroyed. How fully the lessons of Brussels have been learned is well shown by the arrangements which have been made by the authorities of the Ghent International Exhibition. At Brussels the disaster was largely due to the failure of the water supply, so at Ghent a powerful supply has been installed quite distinct from all other water supplies, and the grounds are lined in all directions with water mains, the largest of which are 300 mm., while the greater number are 200 mm. and 150 mm. diam. These mains serve the hydrants scattered throughout the grounds and pavilions. In no part of the whole exhibition, the authorities state, are two hydrants more than 50 metres apart, the average distance being considerably less. The water supply itself is derived from the river Scheldt by means of large automatic pumps at a pressure of five atmospheres, and the hydrants will consequently be capable of throwing water to the top of any of the buildings. These pumps can supply 600 cubic metres of water per hour. But the greatest safety from fire lies in the fact that all buildings are isolated, and in no place less than 10 metres apart, while in practically all cases they are much more. A special fire brigade station is also being installed by the municipal fire brigade in the centre of the exhibition and equipped with motor fire engines and a staff of 25 men. A supply of electric fire alarms connecting with the fire station will also be in operation just as in the London streets, while hand extinguishers will be placed in all buildings. The British section will have yet another safeguard—and one of the greatest—in the fact that the floors are laid direct upon the ground and all platforms packed with earth. This completely prevents the spreading of fire in the space below the flooring, and confines a fire to where it can be reached at once.

West of Scotland Iron and Steel Institute.—At the monthly meeting of this Institute, held recently at Glasgow, a paper dealing with the sequence of reactions in the acid open hearth process by Mr. F. A. Matthewson and Professor A. Campion, was submitted and discussed, and a paper by Mr. C. O. Bannister dealing with the regeneration and recuperation of heat was read.

Surface Combustion.—Sir Oliver Lodge, F.R.S., presided at a joint meeting of the University of Birmingham Metallurgical Society, the Birmingham Metallurgical Society, and the South Staffordshire Iron and Steel Institute, held at the Birmingham University on the 27th ult., the occasion being a lecture on "Surface Combustion" by Professor Bone, F.R.S., of the Imperial College of Technology.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Carburetters for internal combustion engines. Barnett. 21276.
Safety apparatus for railways. Lots. 28983.
Rotary engine or pump. Gabbett Fairfax. 29039.

1912.

Internal combustion engines. Platt. 118.
Carburetters for petrol motors. Wingfield. 1206 and 1207
Alloys for casting. De Buigné. 1316.
Means for propelling ships and other vessels, aeroplanes, flying machines, &c. Orr. 1432.
Carburetters. Shoobridge & Gunstone. 1483.
Gear cutting machines. Dehn. 1579.
Centrifugal pumps. Watson & Billetop. 1639.
Toothed gearing. Guillon. 1665.
Valves and valve mechanisms for explosion engines. Miller. 1720.
Railway signalling and train stopping devices. Kastowsky and Rybak. 1727.
Pipe joints. Row. 1756.
Reduction of tin and similar ores or oxides. Tonkins. 1811
Water tube steam generators. Cooper. 1819
Furnace draught indicators. Von Lossau. 1870.
Cup packings for pistons and plungers. Trist. 1873.
Drill bit sharpening and forming machines. Leyner. 1913, 1915, and 1955.
Manufacture of chain couplings. Bagnall. 1958.
Pistons for motive power engines. Bullard & Weichman. 2072.
Hammer drills. Holman & Holman. 2134.
Carburetters for internal-combustion engines. Binks & Binks. 2179.
Apparatus for promoting the combustion of fuel and effecting the consumption of smoke in boiler furnaces. Hardy. 2680.
Metallurgical furnaces. Cornthwaite. 2709.
Clutches. Tessier. 2745.
Governor to control a motor to run at any speed within a large range of rate of revolution. Belliss & Morcom, Ltd., and Walshe. 2833.
Driving mechanism of motor road vehicles. Dent. 3177.
Mechanism for operating reciprocating tools. Millen. 3215.
Naval destroyer craft. John I. Thornycroft & Co., and Barnaby 3405.
Speed recorders. Brown. 3625.
Fuel supply devices for internal combustion engines. Pullen and Burton. 3745.
Means for automatically regulating or controlling elastic fluid pumps. Smith & Delahanty. 4495.
System of utilising heat in cupolas. Cérieys. 6386.
Regulation of the air supply to rotary kilns. Gilbert. 6603.
Construction of the gas and air passages of regenerative furnaces. Gibbons, Gibbons, and Masters. 6847.
Two-stroke internal-combustion engines. Watkins. 6938.
Machines for indicating irregularities in gear wheels. Sunbeam Motor car Company, and Guy. 7083.
Water-current motors. Struble. 7744.
Carburetting apparatus. Gardiner. 8028.
Regulation of the pressure of the steam supplied for opening ejectors. Soc. Anon. pour l'Exploitation des Procedes Westinghouse Leblanc. 8064.
Vaporisers for use with internal-combustion engines. Halliday. 8081.
Apparatus for feeding boiler furnaces with fuel. Rey. 8099.
Systems and apparatus for heating buildings. Avery. 8124.
Vaporisers for internal-combustion engines. Corson. 9155.
Turbines driven by fluid pressure. Kendal. 9231.
Lock-nuts. Thompson. 9556.
Regulation of continuous combustion internal combustion engines. Otten. 9951.
Locomotives. Dawson & Lucas. 10042.
Method of controlling valves of steam and internal combustion engines. Fornaca. 10451.
Valves for steam engines. Relph. 11206.
Rotary fluid pressure engines. Pavitt. 11468.
Coating iron with aluminium. Uyeno 11836.
Miners' safety lamps. Fattinger 12708.
Rock drilling hammers. Klupfel. 12798.
Apparatus for interlocking hand-levers for railway signals. Phillips & Haughton. 12988.
Automatic regulators for water heaters. Krupitschka. 13583.
Propelling means for aerial machines. Rose. 14375.
Apparatus for roasting or sintering ores. Greenawalt. 14805.
Screw propellers. Holt. 16053.
Compressed air hauling winches. Rud Meyer Akt. Ges. fur Maschinen und Bergbau. 16340.
Rotary engines. Stimson. 16602.
Shaft couplings. Soc. Anon des Anciens Etablissements Panhard and Levassor. 17171
Drill chuck. Bergsten. 17563.
Driving gear for boats. Daimler Motoren Ges. 19169.
Valves for internal combustion engines. Elliott. 19327.
Process and product for purifying acetylene and other gases Granjon. 19838.
Valve actuating mechanism for multiple cylinder engines. Hirst 20228.
Foundry core supports. Sonnet. 20263.
Meters for measuring liquids. Arndt. 20935.
Controlling gear for winding and hauling engines. Worsley Mesnes Ironworks, Ltd., and Bedford. 21028.
Steam generators. Babcock & Wilcox, Ltd. 22098.
Railway-rail joints. Ezard. 22222.
Railway coupling. Seidel & Seidel. 23269.
Turbines. Belliss & Morcom, Ltd., Morcom, Jude, and Edwards. 23915.
Blades for turbines. Belliss & Morcom, Ltd., Morcom and Jude 24657.
Pulley blocks. Smith. 24990.
Automatic couplings for railway vehicles. Willison. 25061

ELECTRICAL, 1911.

Electric heater for fluids. Mann. 26485.
Brush gear for dynamos. Leitner. 28817.
Electric switches. Druseidt. 28912.

1912.

Electric switch and fuse boards. Selby & Preston. 1646.
Electric switches. British Thomson-Houston Company, and Garton. 1680.
Electric tablet systems for working single lines of railway. Blackall & Jacobs. 1852.
Apparatus for the control of electric circuits. Leitner. 1965.
Dynamos. Siddeley. 1999.
Spring shade holder for electric lamps. Munro. 2020.
Electric incandescent lamps. Deutsche Gasglühlicht Akt. Ges. (Auerges). 2284.
Electric lighting systems for motor-cars. British Thomson-Houston Company, and Garton. 2874.
Driving of vehicles by means of internal-combustion engines combined for recuperating purposes with dynamos, accumulator batteries and motors. Pieper. 3281.
Electric fuse switches and switchboards. Berry & Markham. 3338.
Automatically-controlled electric switches. Clifford. 3915.
Electrical switches. Cox. 5280.
Apparatus for charging accumulators. Von Dreger. 5434.
Electrical furnaces. Rennerfelt. 7367.
Portable electric reading lamp. Levi, Rose, & Rose. 9442.
Electric fuse. Boyd & Tannahill. 12273.
Telegraphic photography. Stille. 12709.
Mercury switches. Siemens Schuckertwerke Ges. 14087.
Electric arc lamps. Steinert. 19425.
Self-acting electric switch devices. Schott & Gen. 25518
Moving coil, electrical measuring instruments. Record. 26241 and 26242.

METAL QUOTATIONS.

TUESDAY, FEBRUARY 11TH.

Aluminium ingot	93/- per cwt.
" wire, according to sizes, &c. ......from	112/- "
" sheets " " ...... "	120/- "
Antimony ......£36/-/- to	£37/-/- per ton.
Brass, rolled	9½d. per lb.
" tubes (brazed)	10½d.
" " (solid drawn)	9⅛d.
" " wire	8⅞d.
Copper, Standard	£66/15/- per ton.
Iron, Cleveland	65/3 "
" Scotch	71/3 "
Lead, English	£17/2/6 "
" Foreign (soft)	£16/15/- "
Mica (in original cases), small	6d. to 3/- per lb
" " " medium	3/6 to 6/- "
" " " large	7/6 to 11/- "
Quicksilver	£7/15/- per bottle
Silver	28 7/16d. per oz.
Spelter	£25/10/- per ton.
Tin, block	£223/10/- "
Tin plates	14/7½ "
Zinc sheets (Silesian)	£29/7/6 "
" (Stettin; Vieille Montagne)	£29/17/6 "

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Edited by
WILLIAM H. FOWLER
Wh. Sc., M.Inst.C.E.

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Combustion and Explosions in Oil-fired Furnaces.

The rapid development of the oil carrying trade and the use of oil as a fuel in steamships employed for its transport, render it desirable that the possibility of serious explosions arising from the careless manipulation of the fuel in boiler furnaces should be generally recognised by sea-going engineers. An illustration of the disastrous results that may occur was afforded on December 26 last by an explosion that took place on a new oil ship which was being fitted out at Messrs Swan & Hunter's shipyard at Walker-on-Tyne. As a number of men were engaged preparing for Lloyd's official test of the boilers, which were oil-fired, flames suddenly flashed out of one of the furnaces and overwhelmed nine men who were in the stokehold, five of them being so terribly injured that they subsequently died. The inquest on the unfortunate men has not yet been concluded, and we are therefore not in a position to make any comments on the particular circumstances which led to the disaster, or express any opinion as to responsibility for it. It is permissible, however, and it seems opportune to refer to some features of oil burning and the way in which risks may be incurred in the working of such furnaces, unless suitable precautions are adopted. Unlike coal, oil fuel cannot be thrown on to the furnace in bulk. For proper combustion it must be delivered into the furnace in the form of a spray, and there are several ways of doing this. The oil may be atomised by delivering it under pressure from specially formed orifices, or it may be allowed to trickle out of a supply pipe and be dispersed by the impingement of a jet of steam or compressed air as it escapes, pretty much after the fashion of a scent spray. In the design of these escaping orifices and dispersing nozzles a great deal of ingenuity has been expended, and numerous designs are now in use.

It does not matter much, however, to the final combustion which method is adopted if the atomising is effective. Some

favour compressed air, others the use of steam, while others again prefer the spraying of the oil jet under its own pressure, and the tendency of modern practice is towards this latter method. If air is employed for spraying it requires a separate compressing plant, and to avoid this complication steam is generally used, though in that case when the boiler is started compressed air or an independent steam supply is necessary. Whatever the details of the arrangement, however, it is desirable for proper combustion that the furnaces should be of ample capacity, and to ensure perfect burning should be lined with firebrick to maintain the temperature as high as possible. If the hydro-carbon gases evolved are brought into contact with a relatively cold surface before their combustion is complete, the solid carbon is liable to separate out and form smoke, just as when burning bituminous coal. When steam is used for spraying purposes it is desirable also to remember that the amount absorbed for this purpose may be as much as five per cent. of the total steam generated, and this in the case of boiler installations working with fresh water and surface condensation is a rather serious item, as it necessitates a corresponding increase in the feed water make-up plant. Further, steam does not supply oxygen as air does for combustion, and tends to carry the point of combustion further forward, which with Scotch marine boilers is rather objectionable, as it is liable to make the last stage of combustion occur in the smokebox and funnel. Above all it is important that the air entering the furnace — and about 200 cub. ft. at normal pressure and temperature are required per pound of oil—should be heated before its introduction to the furnace to secure the highest efficiency. Oil flames cannot, like a fire, be regulated to a half rate of combustion. Whatever the quantity of fuel admitted the oil flame, whether it be large or small, must be perfect, and if there are several flames in the furnace it may be preferable to cut out one or more altogether rather than diminish them all equally, if it is desired to reduce the duty of the furnace. A primary essential in all cases is that furnaces should have ample capacity, and inadequate recognition of this is responsible for some of the troubles that have occurred where oil fuel has had to be temporarily resorted to and coal burning grates have been retained in position. Several instances occurred during the late coal strike, when, owing to the failure of the coal supply, many Lancashire boilers were partially fed with oil fuel, injected in a somewhat crude fashion on to firebeds made of slack coal of inferior quality. Quite a number of explosions of flue gases in land installations in Lancashire and Yorkshire came under our notice, and in one or two cases they were sufficiently violent to shatter the brickwork and do considerable damage. As far as investigation could reveal the cause they were found to be due to the accumulation in the flues of partially burned oil vapours—arising from restricted furnace capacity and imperfect spraying—which, mingling with air leakages through the brickwork, formed an explosive mixture which a chance spark subsequently ignited. Such accumulations are of course more likely to occur when the furnaces are damped down for some reason or other, and occasional explosions from a similar cause are not unknown even in connection with coal fuel. With a material so readily volatilised as oil the risk is of course greater. It is for this reason that a special watch needs to be kept over the dampers, to make sure, especially when lighting up, that no unconsumed gases are hanging about in the combustion chamber or flues, and before lighting the oil flames the dampers should be fully opened, so that any accidental accumulations may be cleared away.

POWER TRANSMISSION BY COMPRESSED AIR.

IN a paper entitled "Some Applications of Compressed Air and its Measurement," recently read before the Liverpool Engineering Society, Mr. G. J. Gibbs said that in any but the very smallest installations the matter of air compressing, storage, and distributing plant warranted most careful attention. One point well known in theory but very often ignored in practice was that air compressors should be supplied with cool, clean air as dry as possible. After compression the heated air should be cooled or allowed to cool before it passed into the air mains; otherwise cooling in the mains would entail deposition of moisture which gradually collected and was driven forward with grit and rust, finally causing trouble in the working parts of the apparatus with which it came in contact. Compressed air could be conveyed through pipes for long distances with practically no loss, especially where the demand was intermittent, and where a supplementary air receiver was placed at or near the end of the air main remote from the compressor. In large installations the air compressors required large units of power to drive them, and it was good practice to couple them as directly as possible with the prime movers, with consequent improvement in capital costs and power transmission efficiencies.

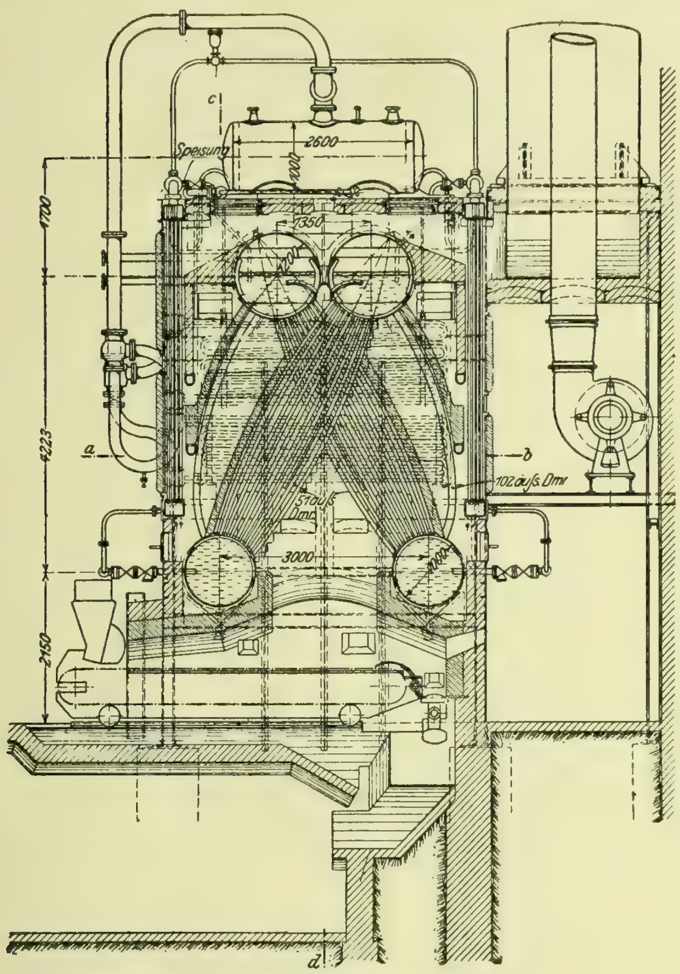
The author considered as an example, a compressor requiring 100 h.p. to drive it. The ideal arrangement would comprise a prime mover capable of driving this compressor and direct coupled to it. On the other hand, where there existed an electric power generating station the tendency was to place the air compressor near the department where the compressed air was required, and to transmit power to it electrically. Under such conditions the sequence of plant would probably be as follows: Prime mover, electricity generator, switches and instruments, transmission cables, motor and starter, and power transmission to compressor crank shaft. Each conversion of energy entailed a serious loss, and instead of a transmission efficiency of 95 per cent. with the simple arrangement, probably less than 75 per cent. efficiency would be obtained under the electric transmission arrangement, while there would be a much increased capital expenditure on account of generator, instruments and switch gear, cables, motor, and a necessarily larger prime mover.

An objection sometimes advanced to compressed air as a power transmitting agent was that leakage was liable to be a great and unknown quantity. The uncertainty as to the rate of consumption of compressed air by the various items of apparatus to which it was supplied and the continuance of the good efficiency of the air compressors had always been a cause of uneasiness to the engineers responsible for the good working of an installation of any considerable magnitude. To meet the requirements of the case the author had designed a combination of variable orifice and manometer. The variable orifice was in the form of an accurately constructed sluice valve, and the manometer, which was not provided with any scale, simply indicated with great certainty and precision one particular pressure difference which might be caused by more or less closing the valve to the flow of air. The valve, which could serve as an ordinary stop-valve, was inserted in the pipe line, and was fitted with a scale to indicate the precise amount of opening, and consequently the precise amount of throttling of the flow, which produced that one pressure difference under which the manometer was operative.

THE BURKHARDT WATER-TUBE BOILER.

THE accompanying illustration shows an interesting type of water-tube boiler, fitted with superheater, designed by Mr. Burkhardt, and manufactured by Mr. J. Piedboeuf, of Dusseldorf. It comprises four drums connected in pairs by bundles of tubes of 2in. external diameter; in these tubes the steam is generated, the water flowing back through larger tubes located along the outside shell of the boiler proper. The circulation of water follows, therefore, two independent but intersecting paths; in the upper boiler, above the ascending pipes, is placed a longitudinal plate to keep the circulation of water steady and to prevent violent variations of the water level. There are 7, 9, or 11 water tubes in one plane, their curvature being so proportioned that they

may be removed when necessary through small holes in the jacket of the upper boiler; these holes serve also to clean the pipes without entering the boiler. The hot gases rise slowly in the high combustion chamber and transfer their heat mainly by radiation, while baffle plates made of refractory clay take care that all the tubes receive their due amount of heat. At the intersection of the nests an additional amount of heat is extracted from the gases by conduction owing to the strong formation of eddies. The gases then flow downwards, and, with a sharp change of direction, on to the two preheaters and smokestack. The two sharp changes of direction of flow of the gases help to shake out the ashes which settle down and can be conveniently removed through the dampers. The system of baffling the hot gases is interesting in that it is arranged so that the warmer gases are nearly always surrounded by layers of somewhat colder gases, thus materially decreasing radiation losses which are further decreased through the hottest gases being nearly always in immediate touch with the heating surfaces.



BURKHARDT WATER-TUBE BOILER.

The boiler shell is made of wrought-iron walls lined with fire clay and consisting almost entirely of flap doors; this increases the accessibility to the boiler and facilitates the cleaning of the economiser, an especially welcome feature as there are no mechanical appliances for this purpose. The preheater can be blown through by steam or compressed air even during the operation of the boiler, by means of nozzles rolled into the upper header. The superheater is placed inside the tube nests, and is in the same path of the hot gases as the water tubes, thus permitting a very strong superheating with a comparatively small surface of superheater, and the attainment of a high steam temperature at low loads. The hot gases flow through side openings in the brickwork shaft where the superheater is located, pass by it and come back to the boiler flues; rotary valves being provided to regulate the admission of the hot gases to the superheater coils. By a steam collector of generous size the steam is kept dry even with a strong demand on the heating surface. We are indebted to the transactions of the American Society of Mechanical Engineers for the foregoing particulars.

THE USE OF HIGHLY-SUPERHEATED STEAM IN LOCOMOTIVES.*

BY GILBERT E. RYDER.

THE development of the modern locomotive has been marked by many improvements, each of which was of some importance in its evolution. Those which stand out most prominently are the ones which have been influential in making possible large increases in capacity and improvements in efficiency. In the earlier years of the advancement of locomotive construction, capacity was the principal object sought for in order to meet the ever-increasing demands of transportation. Only within recent years has the tendency, made necessary by the narrowing margin of railway profits, been that of increasing the efficiency of the locomotive. One of the most recent improvements in this direction, and one which has made possible the largest increases in capacity, and at the same time greatly improved efficiency, is the superheater. The extent of its adoption, prompted by the results of its successful operation, is sufficient testimony to its right to be classed among the leading inventions which mark the progress of locomotive construction. Since the success of this device became established in the United States, about two and one-half years ago, there have been over 6,000 applied to new and existing locomotives in operation on more than 100 railroads.

While the superheater was passing through the experimental stage, several forms and types were tried, furnishing superheat varying within the range of 50° to 250° Fah. above the temperature of saturated steam at boiler pressure. Superheaters furnishing a low or moderate degree of superheat, were tried in service and discarded because of the small economies obtained, as well as the mechanical objections attending their construction and location. The type best adapted to American practice has proved to be the fire-tube superheater furnishing steam with from 200° to 250° superheat.

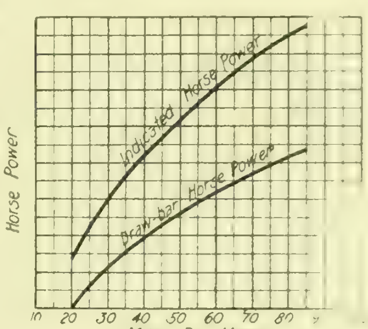


FIG. 1.—CHARACTERISTIC RELATION BETWEEN DRAW-BAR AND INDICATED HORSE-POWER.

The design followed in the construction of this type is based on the principle of the location of coils or units within large boiler flues. The front ends of these units are suitably connected with saturated and superheated steam passages of a header casting, which acts as a steam receiver or collector, and is located in the smokebox. The units extend nearly through the flues and are exposed to the temperatures of the combustion gases, which temperatures range from 1,600° to 600° within the flue. The steam passing through the pipes exposed to this range of temperature is raised to from 200° to 250° above that of the temperature of the steam in contact with the water in the boiler. With this high degree of superheat the steam has a specific volume, roughly 30 per cent. larger than that of saturated steam at the same pressure. In passing from the superheater into the cylinders some of the superheat is lost and the specific volume is reduced to a point approaching that of saturated steam. There is, however, at the moment of cut-off, or at the point where the expansive action of the steam commences, fully 100° of superheat in the steam, which is enough to carry it through expansion and exhaust without condensation. The entire elimination of all losses through condensation, together with the somewhat increased specific volume of the steam, effects, under average conditions, a saving of 30 per cent. in the steam consumption per indicated horse-power and a corresponding saving in fuel of 25 per cent. as compared with a saturated locomotive of the same type, operating under the same conditions.

Before attempting to show what bearing this saving has on the maximum power that the locomotive can develop, there are two points which should be mentioned. First: there

* Paper read before the Western Railway Club, January 1913.

is no increase in pressure attending the addition of heat to the steam in the superheater. Further, the mean effective pressure in the cylinders of locomotives operating at the same boiler pressure, the same cylinder diameter, the same cut-off and stroke, is no higher in the superheater locomotive than in the saturated locomotive. Either of these facts will be evident upon the comparison of indicator diagrams taken from cylinders operating with saturated and with superheated steam. Reasons other than these must then explain the increase in hauling capacity of the locomotive resulting from the use of highly superheated steam.

The increase in hauling capacity is obtained by the increase in efficiency of the locomotive, made possible principally by the entire elimination of condensation and in a small part by the increase in specific volume of the steam. By reason of these conditions, the same cylinder power may be developed at a lower steam rate. A lower steam rate means the evaporation of less water per unit of power, resulting in an increase in boiler capacity and a saving in fuel. Increased boiler capacity can be made to be a source of greater cylinder power, which in turn results in increased drawbar power or greater hauling capacity for the same amount of fuel burned. The increase in drawbar horse-power obtained is, of course, a measure of the increased hauling capacity resulting from superheating.

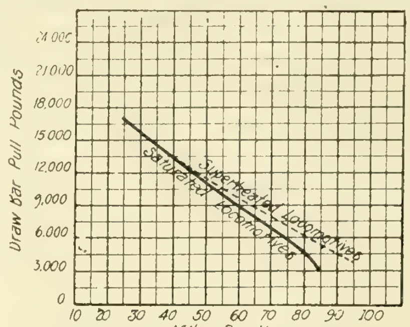


Fig. 2. Pull-speed Curves of Saturated and Superheater Locomotives.

To illustrate the increase in drawbar horse-power obtained, it is convenient to assume two locomotives of the same dimensions and working under the same conditions of boiler pressure, cut-off and speed, developing the same indicated horse-power, one using saturated steam and the other using highly superheated steam. Under average conditions the superheater locomotive will burn at least 20 per cent. less coal per indicated horse-power. Then, if the same amount of coal is burned in the superheater engines as in the saturated engine, and if the efficiency of the boiler is the same, and the engine efficiency remains constant, the indicated horse-power developed will be 25 per cent. more than that of the saturated engine. That is, if a given amount of coal is burned in a superheater locomotive, say 80lbs., a certain horse-power will be developed; then, in order to develop the same power, 100lbs. must be burned in a saturated locomotive. Then, if the same amount of coal is burned in each locomotive, the power developed by the superheater engine will be in the ratio of 100 to 80, or 25 per cent. in excess of the power developed by the saturated engine.

Only about 70 per cent. of the cylinder power, or the indicated horse-power, is available at the drawbar of the tender in the operation of saturated steam passenger locomotives at average speeds. By the addition of the superheater, the weight, dimensions, &c., of the locomotive are not changed materially and, therefore, its efficiency as a whole, will increase over the saturated locomotive at corresponding speeds, because the cylinder power is greater, while the actual machine and tender friction remain practically constant. For example, a saturated locomotive developing 1,000 h.p. at the cylinders on a given amount of coal, 30 per cent. or 300 h.p being consumed in the engine and tender, will have available at the tender 700 drawbar horse-power. A superheater locomotive of the same dimensions operating at the same coal rate, will develop 1,250 h.p. at the cylinders. The loss between the cylinders and the drawbar will practically remain the same, or 300 h.p., which will leave 950h.p. available at the drawbar, which is approximately 35 per cent. greater than that developed by the saturated locomotive. This example shows clearly what increase in hauling capacity is possible by superheating. Results of tests and road conditions have verified these figures many times, but to show just what some of these results have been, it will be interesting to investigate the following curves.

The relation between the drawbar horse-power and the indicated horse-power is shown by the curves in Fig. 1. They are typical curves representative of the indicated and the corresponding drawbar horse-power developed by a modern Pacific type locomotive in passenger service running at various speeds from starting to 85 miles per hour, and illustrate the figures used in comparison given above. The drawbar horse-power is roughly, 70 per cent. of the indicated horse-power at from 65 to 75 miles per hour, and varies in an inverse proportion with the speed. It requires, therefore, greater cylinder power to maintain a certain drawbar horse-power at the higher speeds. When the saturated locomotive has reached its limit in indicated horse-power, the superheater locomotive still has a margin in cylinder power because of the lower steam rate and consequent increased boiler capacity. In other words, it has been shown in Fig. 1, that the engine efficiency, or the percentage of the indicated horse-power which is available at the drawbar, varies with the speed at which the locomotive is operated. The hauling capacity of the locomotive at different speeds depends on the tractive power that can be developed and sustained at these speeds. The maximum sustained tractive effort depends in turn primarily on the boiler capacity.

To show the supremacy of the superheater locomotive, as far as sustained tractive power is concerned, the curves in Fig. 2 show a comparison of the drawbar pulls in pounds of a saturated and a superheated locomotive of the same general dimensions, at speeds ranging from 25 miles an hour to 84 miles an hour for the saturated locomotive, and to 95 miles an hour in the case of the superheater locomotive. At 80 miles an hour, the sustained tractive effort of the superheater locomotive is about 33 per cent. above that of the saturated locomotive, and represents the increased hauling capacity available at the drawbar at this speed obtained by the use of highly superheated steam. In connection with these curves it is interesting to note that the limit in speed of the saturated locomotive with the train that it was pulling was very nearly reached at 85 miles an hour, indicated by the fact that the curve fades rapidly from 75 to 85 miles per hour. The same reference to the other curve would indicate the limit of the superheater locomotive with its train, which was the same weight, was not reached at 95 miles per hour. The conditions limiting the speed probably being those of track, rather than that of insufficient boiler capacity.

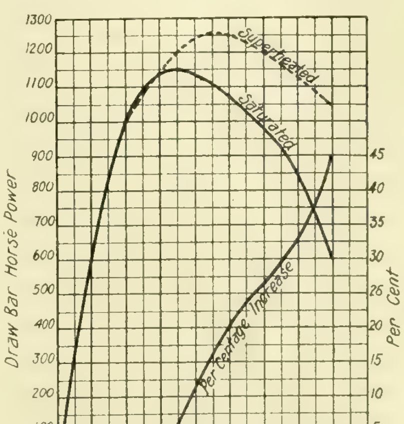


Fig. 3.—Drawbar Horse-power of Saturated and Superheater Locomotives at Various Speeds.

The superiority of the superheater over the saturated engine, or the increased hauling capacity obtained by it, is clearly pointed out by a comparison of the curves in Fig. 3. While they show the drawbar horse-power of the saturated and superheater locomotives sustained at various speeds, considered in Fig. 2, they are representative of results that may be expected by the introduction of the superheater. The maximum drawbar horse-power of the saturated engine was developed at about 33 miles per hour, while the superheater locomotive developed its maximum drawbar horse-power at 50 miles per hour.

The increased hauling capacity realised in actual service by the use of highly superheated steam varies widely. The ton mile basis, however, which is generally used, is not altogether reliable and does not show the true increase in hauling capacity that is obtained. For example, we may consider a saturated locomotive operating a train of eight cars, weighing say 500 tons, over a 100 mile division, which would represent 50,000 ton miles. By the introduction of the superheater it is found possible to haul 10 cars over the same division in the

same time, burning the same amount of coal. When the superiority of the superheater locomotive is considered on the ton mile basis, the increase in ton miles, due to the superheater, in this case, is 20 per cent., while in reality, there may have been many points on the division where the superheater locomotive was developing a drawbar horse-power much more than 20 per cent. in excess of that developed by the saturated locomotive. This point is illustrated by the graphic log shown in Fig. 4, which was obtained from actual tests of practically the same weights of trains operated over 81 mile division, first by a saturated and then by a superheater locomotive. When considered on a ton mile basis, the superheater locomotive shows no superiority over the saturated locomotive. However, by comparing various parts of the run, it is evident, that the superheater locomotive was developing more drawbar horse-power, or a greater hauling capacity than the saturated. It is also evident from the log, that the saturated locomotive was taxed very nearly to the limit of its capacity throughout the entire run in order to make the schedule, and coming into the terminal, it was necessary to maintain a high speed to the very end of the run. While in the case of the superheater locomotive, the speed over the first half of the run was considerably higher than was necessary to maintain the schedule; evident from the fact, that the speed curve drops below that of the saturated engine over the latter part of the division. The speed on the grades, and on the difficult parts of the run was also higher than the saturated locomotive could make. The maximum speed obtained by the saturated engine was 84 miles an hour, while the superheater engine at the same point on the division reached nearly 93 miles an hour. It is, therefore, apparent that the increased hauling capacity due to the use of superheated steam is best measured by the increase in power obtained at the drawbar.

In a preceding paragraph, it was pointed out that the hauling capacity, or the sustained tractive effort at different speeds depends on the boiler capacity and the engine efficiency. It is by reason of the increased boiler capacity, due to the entire absence of cylinder condensation, together with the gain due to the greater specific volume, that it is possible to develop a higher indicated horse-power, and the attending increase in drawbar horse-power realised with superheated steam, that the work done per pound of steam is increased. This increase may be made useful, either by longer cut-off at the same speed, or greater speed at the same cut-off.

By superimposing the indicator cards taken from a saturated and superheated locomotive of the same general dimensions, operating at the same steam rate, it will be noted that the area of the superheater engine card is greatly in excess of the saturated engine card, due to the greater cut-off at which the former may be operated. The difference does not, however, measure completely the increased boiler capacity that may be obtained by superheating. In order to utilise to the fullest and most economical extent, the increased capacity of the boiler obtained by the superheater, it is not enough to merely increase the cut-off or the length of admission, because if this only is done, the steam will not be used at the same efficiency. That is, the cut-off coming later in the stroke, the steam does not have an opportunity to expand through the necessary range to ensure its most economical use. The terminal temperatures and pressure are high, and consequently, the losses are greater. The diameter of the cylinders should be increased in proportion to the increase in boiler capacity to realise to the fullest extent the possible economy. This can be done without any limitations from fear of condensation. In new locomotives, it can be provided for in the design. When superheaters are applied to existing locomotives the adhesive factor and the strength of the parts to withstand the greater piston thrusts must be taken into account. It is generally possible to increase the cylinder diameter to some extent without danger. This fact makes the superheater an economical remedy for locomotives where cylinders are too large for the boiler, or, in other words, for locomotives deficient in boiler capacity.

Before leaving the subject of increase in hauling capacity attending the use of highly superheated steam, it is pertinent to mention its effect upon the tonnage rating of locomotives. In the rating of locomotives the boiler capacity is in most cases either directly or indirectly the limiting factor and the maximum starting effort that the locomotive is capable of exerting is of secondary importance. When considering the rating of locomotives in pusher, slow drag service and heavy switching service, the maximum tractive effort become the leading factor in fixing the tonnage of the trains to be hauled, but even in these instances, the sustained tractive effort is in many cases made dependent on the boiler capacity. Passenger locomotives and freight locomotives in the rating of which the speed element enters in, are rated according to the ability of the boiler to furnish steam maintaining a certain tractive effort at the desired speed, the maintaining starting effort being only a fraction of the maximum starting effort of the locomotive, so that in almost all cases it may be said that the tonnage rating is in reality based on the capacity of the boiler. Then, inasmuch as the increased hauling capacity is based upon the ability of the boiler to furnish sufficient efficient steam, the superheater installed in the boiler provides a reserve source of power which is amply sufficient to meet the demands that are made upon it. In fact, it has been said that the superheater locomotive cannot be overloaded, but that it will pull all that it can start. It is also a fact, that as the demands for power are increased in the operation of the superheater locomotive, the efficiency increases, which makes it possible to beat it under conditions where a saturated locomotive must be favoured.

That the possibility exists of obtaining economies in coal consumption and large increases in hauling capacity by the

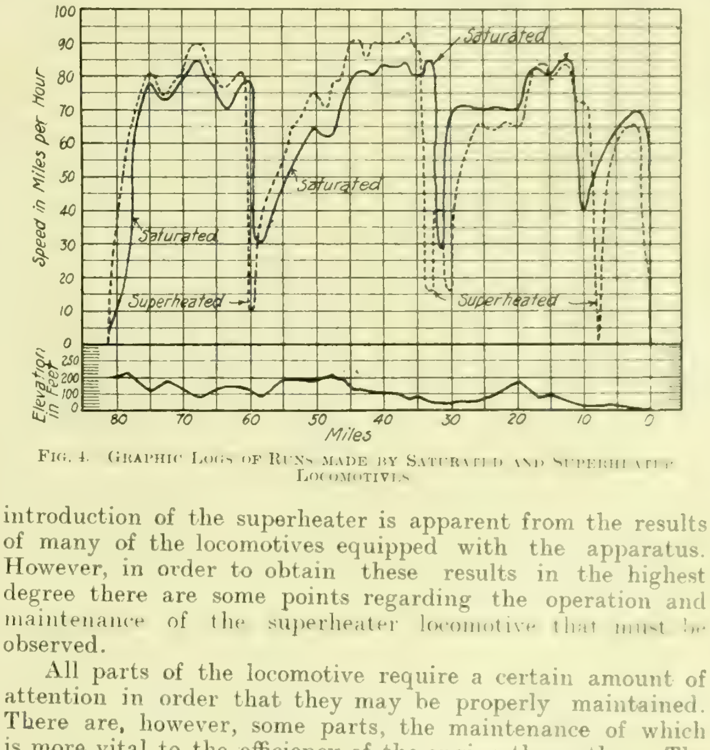


FIG. 4. GRAPHIC LOGS OF RUNS MADE BY SATURATED AND SUPERHEATED LOCOMOTIVES.

introduction of the superheater is apparent from the results of many of the locomotives equipped with the apparatus. However, in order to obtain these results in the highest degree there are some points regarding the operation and maintenance of the superheater locomotive that must be observed.

All parts of the locomotive require a certain amount of attention in order that they may be properly maintained. There are, however, some parts, the maintenance of which is more vital to the efficiency of the engine than others. The superheater may be considerably neglected without resulting in a complete engine failure, but any neglect will affect its efficiency and the ultimate results in economy that may be realised will not be obtained. One instance which I recall was that of an engine in passenger service, running out of Chicago. For some time this engine had been reported as not steaming well. The front end was examined and there were found to be three holes of about ¼in. diam. in the unit pipes, having been cut there by the action of the steam from a leak in the front flue sheet flange. Had there been a leak of this size in the steam pipe of a saturated engine, it would have been impossible to operate at all. The superheater locomotive, however, had a sufficient margin in steam capacity to make the schedule time over the division, although the economy that should have been obtained was not being realised.

This incident is mentioned to bring out the importance of making periodical inspections and tests of the superheater, and particularly of the front end, in order to find any leaks that will affect the economy of the operation be-

fore they have become so large that the engine must be taken out of service to repair them. The practice of making an inspection every 30 days will ensure a better economy in the performance of the engine, as well as prevent any small leaks becoming so large as to necessitate extensive repairs.

Another point to be carefully watched in the maintenance of the superheater locomotive is that of keeping the large flues clean so that the flow of gases through them will not be retarded or altogether stopped. The water heating surface in the boiler of the superheater locomotive is less than that of the boiler of the same design for saturated locomotives, and the large flues constitute a large percentage of this surface. If cinders are allowed to accumulate in them they will become partially or wholly stopped up, and the water heating surface which they represent will become inactive. Stopping up of the large flues also influences the efficiency of the superheater inasmuch as the flow of the gases is retarded and the amount of heat available for superheating thereby restricted. The flue cleaning periods cannot be fixed to apply to all operating conditions; the quality of the coal used principally governs the fixing of these periods. With some classes of coal, it is necessary to clean the flues every trip, while with others, engines will run days and even weeks without any attention. When the flue cleaning periods have been fixed by the operating conditions, they should be strictly adhered to.

For the same reason that the flues should be kept clean, care should also be taken to prevent the occurrence of leaks. From a maintenance standpoint, the care of the flues necessitates the use of the flue roller, prosser expanders and beading tool. In using these tools, experience has proven that the prosser should be given the preference, using the roller only when absolutely necessary, and omitting the beading process unless the condition demands that it be used. The designs of tools that have given the best satisfaction in carrying out this work are the roller, consisting of five rolls, and prosser of not less than twelve sections. Specific flue conditions, of course, demand that specific methods be used in caring for them, but the above applies in general. The maintenance and operation of superheater locomotives are very closely allied, and the value of good maintenance methods and conditions can be reduced by improper operation. While the operation of the superheater locomotive does not differ in general from that of properly operating saturated locomotives, there are certain practices, which, if carefully followed, will make it possible to realise, to a fuller extent, the increased capacity and efficiency of a locomotive comprising superheater equipment.

The firing should be light and regular, on account of the fact that the coal economy is improved by the superheat, thereby necessitating the burning of a smaller amount of coal to develop the same power. The aim of the fireman on a superheater locomotive, in order to get the best results, and to make the work easier for himself, should be to maintain a fire that will result in the highest firebox temperatures. This practice will ensure, as far as combustion is concerned, the highest degree of superheat and, therefore, the best efficiency for the locomotive.

In running locomotives equipped with superheater, the engineer should, in addition to satisfying himself that all parts are operative, carry the water in the boiler as low as operating conditions will permit. The superheater provides the same power on the evaporation of from 30 to 35 per cent. less water, which, of course, means that water will not drop so fast in the boiler with the injector cut down, or shut off. The practice of carrying water as low as possible, results in a higher efficiency of the superheater, because the quality of the steam is better, or the moisture which it contains is less, when the water level is farthest away from the point where the steam enters the throttle box. Whatever moisture there is in the steam when it enters the throttle valve must be evaporated in the superheater before superheat can begin to be realised. Therefore, as the amount of water in the steam is increased, the efficiency of the superheater is decreased. On account of the difference in the amount of heat required to evaporate the water compared with that necessary to raise the temperature of the steam in the superheater, water admitted with the steam will reduce the economy that the superheater is capable of effecting.

One more important point on the subject of operation is, that of the proper lubrication of the valves and cylinders. Because of the high temperature of the walls of the valve and cylinders in superheater locomotives, oil with a flash point as high or higher than these temperatures should be used. While it has been shown that oil enclosed in the steam may be raised to a temperature several hundred degrees above that of steam coming from the locomotive superheater, the temperature of the cylinder walls, valve and steam chests, does not drop instantaneously when the flow of steam is shut off. If the oil used has a flash point or carbonising point below the temperature of these walls, the steam shut off and air admitted through the vacuum valves, the result must be a carbonisation or burning of the oil. So in order to ensure against the carbonisation of the oil in the cylinders, valves and the gumming up of the rings and clearance spaces, it is recommended that the engine throttle be slightly cracked while drifting, or independent drifting valves used to admit steam to the cylinders while the engine is drifting.

In conclusion, we may sum up that the superheater locomotive is capable of producing a marked increase in hauling capacity, which is best measured in drawbar horse-power, a saving in fuel, and a reduction in the cost of transportation, made possible by the increase in hauling capacity. In order, however, to obtain these results to their fullest extent, certain care must be taken in operating and maintaining it.

CONVEYERS FOR FACTORIES.

AT a meeting of the Manchester Association of Engineers held on Saturday last, Mr. W. H. Atherton, M.Sc., read a paper entitled "Continuous Package Conveyers for Factories." He said that all the means employed for moving goods from one point to another could be included under two heads: (1) Intermittent methods such as the wheelbarrow, crane, and cage hoist, and (2) Continuous methods which included the numerous family of conveyers and elevators, and some types of ropeways. The former had been used for centuries, while the latter were of comparatively recent application. In the most general sense one might include under the term "conveyer" any kind of truck, carriage, locomotive, canal boat, ship, crane, overhead runway, telpher, transporter, or ropeway; but in the restricted or specialised technical sense, a conveyer was a machine capable of carrying goods in a continuous stream, usually in one direction only, and having for its most characteristic feature, some form of endless band or chain belt built up of a series of metallic links, with its attached carriers. This definition, however, did not include the inclined roller tracks or runways now so much used in connection with light-cased goods, and often referred to as gravity conveyers. In an engineering workshop the transportation work was essentially of an intermittent and miscellaneous character, demanding the use of overhead travelling cranes, telphers, and pulley blocks. In such situations conveyers were seldom applicable; because they did not possess the same flexibility and radius of action as cranes, and they were not at all suitable for moving isolated heavy articles at considerable intervals of time. On the other hand, the transportation work was of a fairly uniform and continuous character in large warehouses and productive factories; such as spinning mills, breweries, bottling stores, paper mills, soap works, tobacco and biscuit factories, where conveyers could often be applied with great economic advantage. Conveyers were usually installed for the following reasons: (1) To save labour and time. (2) To increase the output, and (3) To utilise existing buildings for new purposes. Although the mechanical construction of conveyers was simple, yet the variety of types was so great and the conditions of application so diverse that it often became quite a complex engineering problem to design the most suitable scheme of conveyers to meet existing local conditions and requirements. The designer also experienced the ever-present difficulty of endeavouring to reconcile as far as possible the conflicting demands of low first-cost and efficiency in operation throughout a reasonable period of years. This difficulty was by no means unknown in other branches of engineering, but in the case of conveying machinery commercial considerations seemed to be specially insistent. The desire on the part of many purchasers to cut the price at all hazards was a

mistaken policy, which often resulted in machinery that was cheap but not economical, and sometimes led to serious trouble. The author next proceeded to describe very fully the various types of package conveyers, and illustrated their application to different industrial purposes by views and details of numerous actual installations.

COMPARATIVE COSTS OF PRIME MOVERS.

In a paper on "Internal combustion Engines," read before the Yorkshire section of the Institution of Electrical Engineers, Mr. K. Cox referred to the comparative costs of installing and working various prime movers for the generation of electricity, and to recent developments in the design of internal-combustion engines.

In the case of an extension to a steam plant, he said, where there were existing boilers capable of giving enough steam, a turbo set, with its lower capital cost, would probably prove the most satisfactory expedient, and in the case of a very large installation, where space was of prime importance, and particularly where heavy peak loads had to be carried, the turbo scheme must also offer the most satisfactory solution. On the other hand, where a new plant had to be erected, and more especially where coal was expensive and the load fairly steady, the internal-combustion engine had many points in its favour. There was not very much difference between the capital cost of steam, gas, or Diesel engine stations, when all the necessary auxiliaries, buildings, and foundations were taken into consideration.

The steam station consisted of boilers with their seatings, flues, and chimney stack, also economisers, superheaters, and feed pumps. The turbo-generator would certainly be much cheaper than the gas or Diesel driven set, but there also must be taken into consideration the necessary condensing plant and high-pressure piping. The gas station would consist of a gas producer plant, gas engine, and generator, water circulating pumps and air compressor for starting purposes, and there would be an engine-house and small shed for covering the boiler and gas producer auxiliaries. The Diesel engine station would cost somewhat more than the steam station; but although the Diesel engine was a comparatively expensive piece of machinery it was complete in itself; the only accessories being a circulating water pump and fuel tanks.

The comparative capital cost for a station of 650 kw., which would be a typical installation for the supply of power to a moderately large works or factory, would be as follows:—

APPROXIMATE CAPITAL COST.

650 KW. TURBO-GENERATING PLANT.

	£
Power-house, crane, chimney, and fittings	2,500
One B. and W. boiler, mechanical stoker, and internal superheater	1,300
Motor and gear for driving stokers	50
Setting for boiler	150
One 650 kw. turbo-alternator set with condenser	4,000
One boiler feed pump	100
Piping and valves—steam £500, water £150	650
Switchgear	100
Total capital cost	£8,850

650 KW. GAS ENGINE INSTALLATION.

	£
Two 500 b.h.p. gas engines direct-connected to 325 kw. direct-current generators, with fittings	5,850
Air starting equipment of motor-driven compressor and tanks	150
Water circulating pumps (motor-driven)	60
Piping for gas, air, water, exhaust, and silencers	210
1,000 b.h.p. continuous-pressure gas plant, coolers, scrubbers, cleaning fan, gas-holder, and boiler	2,250
Foundations for gas plant	200
Engine-house and foundations	800
Switchboard	120
Total capital cost	£9,640

650 KW. OIL ENGINE INSTALLATION.

	£
Two 500 b.h.p. oil engines direct coupled to 325 kw direct-current generators, with fittings	9,640
Circulating pump	50
Piping for water, exhaust, and silencers	200
Engine-house and foundations	1,000
Oil storage tank £70, switchboard £120	190
Total capital cost	£11,080

Assuming that the station would be worked 3,000 hours a year, the running costs per week would be as follows:—

APPROXIMATE RUNNING COST.

650 KW. TURBO-GENERATING PLANT

	£	s.	d.
Fuel: 17lbs. of steam per kilowatt hour, including auxiliaries (coal 10s. per ton, 10 per cent. for standby)	25	0	0
Labour: Stoker 30s., attendant 35s., labourer 20s.	4	5	0
Oil, waste, and stores	2	0	0
Repairs and maintenance	1	14	0
Interest: 5 per cent. on £8,850	8	10	0
Depreciation: 7½ per cent. on turbo set	9	3	0
2½ per cent. on buildings	1	9	0
Total running cost	£52	1	0

Cost per brake horse-power, 0·232d; per kilowatt-hour, 0·348d.

650 KW. GAS ENGINE INSTALLATION.

	£	s.	d.
Fuel: Bituminous slack at 10s. per ton (1¼lbs. per brake horse-power hour, including standby)	13	11	0
Labour: Driver 35s., gas plant man 30s., labourer 20s.	4	5	0
Oil, waste, and stores	1	7	0
Repairs and maintenance	1	19	0
Interest: 5 per cent. on £8,850	8	10	0
Depreciation: 7½ per cent. on engine and producer	12	15	0
2½ per cent. on buildings	0	8	0
Total running cost	£43	10	0

Cost per b.h.p. hour, 0·195d.; per kilowatt hour, 0·292d.

650 KW. OIL ENGINE INSTALLATION.

	£	s.	d.
Fuel: Oil at 50s. per ton, 0·45lb. per b.h.p. hour	27	2	0
Labour: Driver 35s., labourer 20s.	2	15	0
Oil, waste, and stores	2	17	0
Repairs and maintenance	1	19	0
Interest: 5 per cent. on £11,080	10	13	0
Depreciation: 7½ per cent. on engines	14	11	0
2½ per cent. on buildings	0	10	0
Total running cost	£60	7	0

Cost per b.h.p. hour, 0·268d.: per kilowatt-hour, 0·147d.

Where gas existed as a by-product the gas engine had tremendous advantages; and although in Great Britain there was an immense quantity of blastfurnace and coke-oven gas available, and often going to waste, only a small percentage of it was economically used in internal-combustion engines. Much greater advantage was taken of these by-products in Germany, where about 30 per cent. of the available gas was used in gas engines, against only 5 per cent. in this country. Probably this was due largely to the fact that during the last 10 or 15 years there had been great developments in the iron industry in Germany, and it was in such establishments that large gas-engine units could be most advantageously employed. In this country, where the iron industry had been in existence for so many years, the old steam plant could be only gradually replaced by the more efficient internal-combustion engine. Where a new plant was being installed the advantages of gas-driven electric plant were obvious, as the demand for power in the case of a modern colliery or coke-oven plant with by-product recovery apparatus was so great that the utilisation of gas engines to obtain the maximum output from the waste gas was almost a necessity, for the reason that a gas-fired boiler and steam plant would not in general give more than 35 per cent. of the power that could be obtained from a gas engine using the same volume of gas.

On the Continent the development in gas engine work had been mostly in the horizontal double acting type of large power, units of 2,000 b.h.p. to 3,000 b.h.p. being common. These engines were built on both the two and the 4 cycle principles. The usual arrangement was to put two double-acting cylinders in tandem working on one crank, and for the larger powers four cylinders on two cranks, with the fly-wheel and generator between the cranks. Comparatively few of these engines were installed in this country, the largest being a 2,400 b.h.p. and a 1,200 b.h.p. Nürnberg engine at the Bargoed Colliery in South Wales. These engines had cylinders of 51¼in. diameter with a 43·3in. stroke, and ran on coke-oven gas. The 2-cycle engines were made on the Koerting and Oechelhauser principles. In both these types the piston overran the ports through which the burnt gases were forced by the incoming charge, this new charge being pumped into the cylinder by separate gas and air pumps. By this means the piston received an impulse at every stroke and the exhaust valves and gear were eliminated. Engines developing 2,000 b.h.p. in one cylinder had been made on this principle, the cylinder diameter being 43in. The greatest disadvantage of this class of engine was that when working on a dirty or tarry gas there was a danger of the gas pumps getting clogged and causing the gas piston to seize in the cylinder, with the result that unless the driving gear operating this piston was very strong it became strained or broken.

There was much to be said in favour of the smaller units, and the following considerations were worthy of notice:—(*a*) The thermal efficiency of a moderate-sized unit was not less than that of a large unit; (*b*) the risk of failure of vital parts in large engines was certainly greater than in small ones; (*c*) the capital cost and space occupied by a number of smaller units was very little more than that of a large unit; and (*d*) a number of units gave a much more "elastic" station and a greater factor of reliability.

One of the greatest difficulties in the case of large double acting gas engines was the cooling of the moving parts. In engines working on producer gas where the cylinder did not exceed 23in. the heat of the explosion absorbed by the piston could be dissipated by the cooling effect of the cylinder walls on the sides of the piston. Where pistons above this size were required, and especially in the case of a double-acting engine, it was necessary to water-cool the piston and piston rod; and as the piston speed of such an engine was from 800 ft. to 900 ft. per minute the inertia of the water caused many difficulties, making joints on the articulating pipes conveying the water to the piston no easy matter. The same trouble applied to the exhaust valves of large engines which had to be water-cooled; and, as it was customary to make the piston rod and exhaust valve stems of steel considerable pitting and wear took place, due to the condensation of the exhaust gases, which had always an acid tendency on the cooled surfaces. One of the main disadvantages of large cylinders was the danger of cracking the cylinders and cylinder heads, due to the temperature variation. Owing to the high-pressure which occurred, it was, of course, necessary to have cylinder walls of considerable thickness, and when one considered that the temperature at the moment of explosion was from 2,500 to 3,500 Fah. on the inside of the cylinder, and that there was cold water on the outside, it would be seen that the internal strains in a thick wall of metal must be enormous. The design of the cylinder for these large-power horizontal engines must of necessity become very complicated, and the mechanism for operating the large diameter valves was very involved, requiring the most careful adjustment and attention. The piston rods and glands required most careful attention, as the action of the gas was extremely erosive in case of a leaky gland, and if not immediately attended to cut a groove in the piston rod.

To get a fairly high-power engine, say, 1,000 b.h.p., there was the alternative of a small number of large cylinders or a large number of small cylinders. To avoid some of the above troubles the multi-cylinder vertical engine had been developed on the lines of the high speed steam engine having forced lubrication to the bearings and an enclosed crank case. The stroke being fairly short, the number of revolutions was high, the whole engine being compact. On the 4-cycle principle each crank received one impulse in two revolutions. A further advance on this type was the vertical tandem gas engine of the vertical single-acting type, on the 4-cycle, and cylinders arranged two in tandem, so that the explosion stroke of one cylinder was the suction stroke of the other. A very even pressure was exerted on the crank pin, and an even turning moment equal to the highest class steam engine was produced. This type, like the high-speed steam engine, was particularly adapted for electric driving. In the case of engines having only one or two cylinders it had been found necessary to drive the generator through a flexible coupling. Such couplings were a source of trouble, and the elimination of them was, he said, desirable. Again, with the higher speed of the vertical multi-cylinder engine a smaller and cheaper dynamo might be used. Other advantages were that the vibration was less, due to the inertia of the reciprocating parts being smaller; consequently, lighter foundations could be used. Owing to the smaller volume of the cylinders silencing of exhaust was less difficult.

In the duplex vertical engine the cylinders were placed side by side, and connected at top and bottom. The inlet ports were arranged in one cylinder and the exhaust ports in the other. The pistons moved together, the cranks being almost in line, one crank having a slight advance over the other to give lead. The pistons over-running the ports dispensed with valves in the power cylinders. The advantages claimed for this type were the elimination of the cam shaft, and that the cylinder being valveless was of simple construction It appeared to the author that this engine must have the inherent defects of all 2-cycle engines, viz., comparatively high fuel consumption, difficulty in running on any but the cleanest gas, due to the gas pumps and valves becoming fouled with tar and dust, and the necessity of water-cooling the piston. It would also appear difficult to balance an engine of this type, as the reciprocating mass of the two pistons working together must be very great.

One of the principal advantages of the oil engine was that direct economical use could be made of heavy residual oils, and this form of fuel was extremely easy to handle and store and occupied a minimum of space. It was quick and easy to start, there were no stand-by losses, and the whole installation required very little floor space. Several Continental manufacturers were building the oil engine on horizontal lines. These were, of necessity, slow running, and were consequently of great weight and occupied a large amount of floor space. The large size of dynamo required for the output at this low speed was a further disadvantage. The air compressor for starting and also for injecting the oil into the cylinder was now almost universally direct-driven from the end of the crank shaft. This was either a two or preferably a 3-stage machine, capable of compressing up to 1,000lbs. per square inch. provided with intercoolers between the stages and the air was stored in wrought steel tanks. Air was taken from one of these tanks for starting purposes, one or more of the engine cylinders being for the time used as an air motor. The 2-cycle oil engine was more specially adapted for marine work, as the reversing mechanism was much simpler than on the 4-cycle. It had the disadvantage, however, of requiring about 10 per cent. more fuel than the 4-cycle engine.

With the experience gained and improvements in design the modern gas or oil engine was as reliable as a good steam engine. The cost of upkeep was little, if any, more than a steam engine, provided that reasonable and intelligent care was given to the running.

Tests for Safety Lamps.—The Home Office has issued a revised memorandum on the testing of safety lamps for coal mines in substitution for those previously issued. Flame safety lamps, it is laid down, must be provided with double gauzes so constructed that the lamp cannot be put together without the gauze. The tests include dropping the lamp from a height of 6ft., dropping a 5lb. weight on it, strength and heat tests for the glass, and standing in an explosive atmosphere. Electric safety lamps will also be dropped from a height of 6ft. and tested in an explosive mixture. A flame lamp is required to give a minimum candle-power of 0·30 for ten hours, and an electric lamp one candle power all round in a horizontal plane for nine hours.

MODERN CONDENSING SYSTEMS.*

By A. E. Leigh Scanes, M.A.

It is the object of this paper to indicate as briefly as possible the lines along which development in condensing systems has taken place during recent years and will probably continue in the future. It will be shewn that the tendency is towards smaller and cheaper plants of high vacuum efficiency, and towards simplicity in auxiliaries as exemplified by rotary pumps. So much has already been written about the ultimate advantages of condensing systems as opposed to the initially cheaper non-condensing types of engines that nothing need be said under this head. The same is true to a lesser extent regarding the degree of vacuum it is desirable to maintain for maximum overall efficiency. In practice it is necessary to investigate each particular case with regard to local conditions, as to the cost of coal and the water supply available for cooling. Generally speaking, it will be found that for reciprocating engines vacua of from 26in. to 27in. are most suitable, and for turbines from 27in. to 29in. Here and in all calculations which follow the barometer has been assumed to be 30in. of mercury.

For high-pressure steam turbines an approximate saving of 5 to 6 per cent. in steam consumptions can usually be effected between 27in. and 28in. vacuum, and 7·5 to 9·5 per cent. between 28in. and 29in., and 13 and 15 per cent. respectively for low-pressure turbines.† For low-pressure turbines in connection with winding engines and similar plants, care must be taken that air is not pumped into the condenser, if a very high vacuum is to be maintained. From the above gain there must be deducted the increased capital outlay, running cost, and depreciation of the condensing plant, over one for 27in. vacuum, which may be taken as the minimum desirable vacuum under normal conditions.

Types of Condensers.—Condensers can be divided into two main types and five divisions:—

(1) Surface.—(*a*) Cooling water passing through tubes, the usual form. (*b*) Evaporative where steam is condensed in the tubes by a small quantity of water flowing over their exterior.

(2) Jet. (*a*) High level or barometric. (*b*) Low level. (*c*) Ejector.

The first type is used when water is not available at a reasonable cost for boiler feed purposes.

Choice of a Plant.—Figs. 1 and 2 show a series of curves from which it is possible to compare the relative advantages of the different types of plant. In calculating these curves in Fig. 1 allowance has been made for the original cost of condensers, cooling towers (when necessary), and foundations. In Fig. 2 depreciation at 12 per cent. per annum and running cost at ½d. per unit have been capitalised at 5 per cent. If the depreciation and running cost were capitalised at 4 per cent. the difference between the curves for surface and jet condensers would not be as much, and in any case the greater freedom from troubles, smaller number of working parts, and reduced attention for cleaning, make the jet plant the most desirable when it can possibly be used. These figures do not pretend to be more than an approximate guide, as so many conditions must be taken into consideration that any hard and fast rule is impossible.

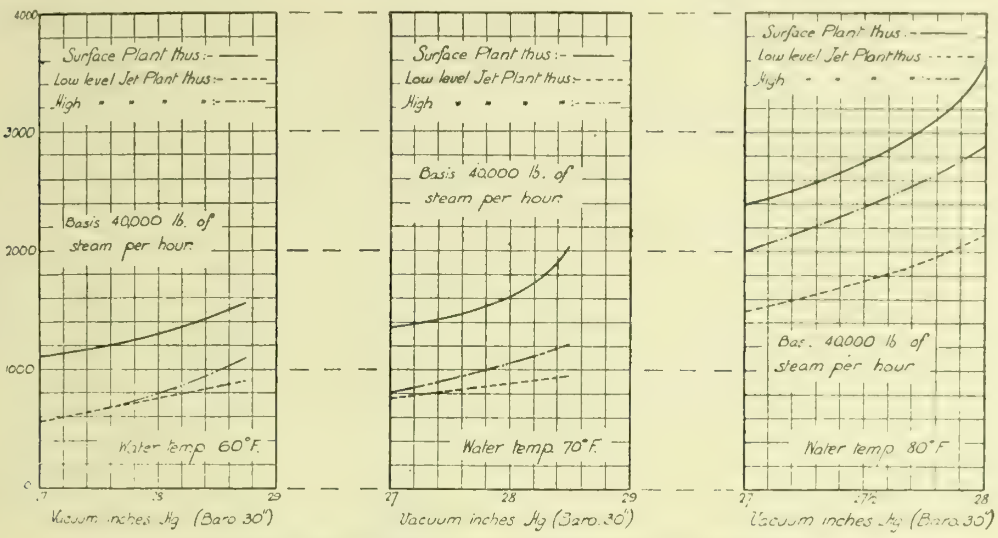


Fig. 1. Comparison of Initial Cost of Various Types of Condensers.

Surface Condensers.—In the earlier types of surface condensers a very low rate of heat transmission was usual, about 350 B.Th.U. per square foot of surface per degree Fahrenheit mean temperature difference. The above rate would give condensation of 5lbs. or 6lbs. per square foot per hour for moderate vacua and water temperature.

From the point of view of reliability much has been said in favour of large surfaces, since they were supposed to require less attention and cleaning to maintain a high vacuum. This may be true with moderately clean water. With some kinds of bad water, however, marine practice has shown that small surfaces are best for reducing the formation of scale, owing to the increased water velocity. Furthermore, this increase of velocity through the tubes also increases the rate of heat transmission from the metal to the cooling fluid.

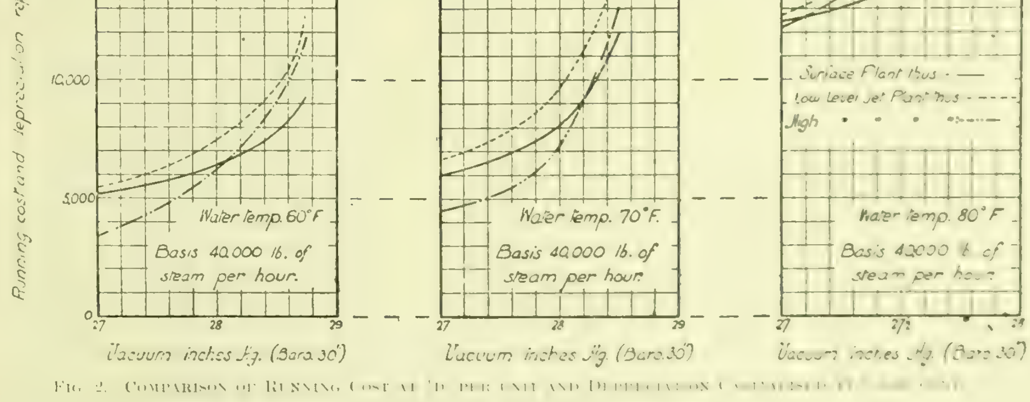


Fig. 2. Comparison of Running Cost at ½d. per Unit and Depreciation Capitalised at 5 per cent.

Fig. 3, taken from "The Engineering Review," Vol. 24, No. 140, shows experimental results obtained by various authorities, connecting the rate of transmission and water velocities. It will be seen that considerable difference of

* Paper read before the Institution of Mechanical Engineers, February 14th, 1913.

† K. Baumann on "Recent Developments in Steam-turbine Practice." Inst. of Electrical Engineers, December, 1911.

opinion exists, and it is necessary to observe the greatest care in details of design to obtain results corresponding to even a mean of the curves shown.

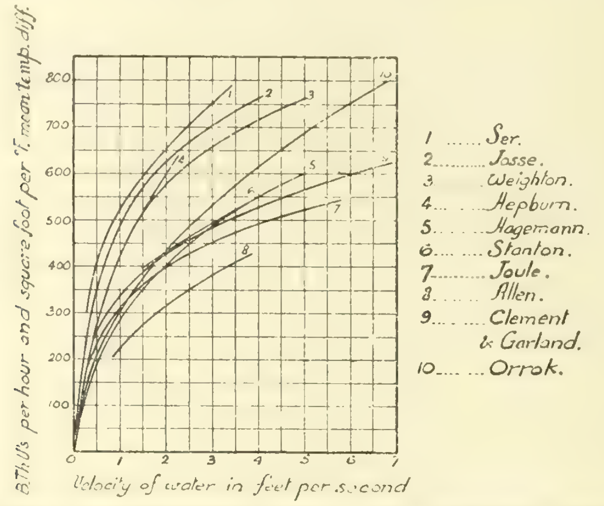


FIG. 3. HEAT TRANSMISSION FROM STEAM TO WATER IN SURFACE CONDENSERS

TABLE I.—*Burnley Corporation.*

Extract of Official Test on 20 per cent. Overload.

1,500 kw. Turbine, 2,100 revs. per min., 3,100 sq. ft. Condenser.

Power of Auxiliaries, 28·5 b h.p.

Time.	Throttle Pressure	Throttle Temperature	Inlet Pressure	Temperature before Throttle	Vac In. Hg Bar. 30in	Inlet Water Temperature	Hot-well Temperature	Net Weight of Steam Condensed.
a.m.	Lbs. per sq. in.	Degs. Fah.	Lbs. per sq. in.	Degs. Fah.		Degs. Fah.	Degs. Fah.	Lbs. per hr.
1·30	127	456	99	470				29,500
1·35	126	460	100	475				29,200
1·40	126	460	100	475				29,000
1·45	126	459	100	475				29,000
1·50	124	460	100	475	28·9	41	68	29,800
1·55	124	466	100	480	mean			29,300
2· 0	124	472	101	485				29,250
2· 5	123	481	102	495				29,200
2·10	123	489	106	500				28,550
2·15	123	490	107	500				28,250

Average steam condensed, 29,105lbs. per hour. Pounds condensed per square foot of surface = 9·4. Hot well of 68 Fah. corresponds to a vacuum of 29·32in. mercury. Therefore, 28·9in. = 98·56 per cent. vacuum efficiency, that is 98·56 per cent. of 29·32in. mercury.

A common cause of failure is throttling of the flow of steam among the tubes, a large drop of vacuum resulting between the steam inlet and the air-pump suction. Many methods have been tried to overcome this by keeping a constant steam velocity, such as spacing the tubes farther apart near the steam inlet, making the condenser shell heart-shaped to offer a large surface at the top, gradually decreasing to the air outlet, and running passages among the tubes. The first and last have been adopted by the British Westinghouse Electric and Manufacturing Company, with great success, and in their opinion these offer the best all-round results when combined with a cylindrical shell which offers many advantages in manufacture and is mechanically strong.

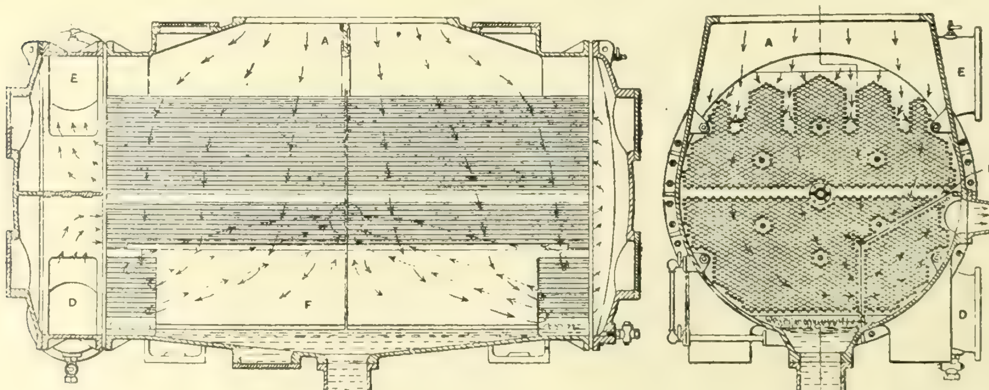


FIG. 4. DIAGRAM OF SURFACE CONDENSER (WESTINGHOUSE).

A, steam inlet; B, condense outlet; C, air-pump suction; D, cooling water inlet; E, cooling water outlet; F, baffle in front of air-pump suction to prevent any steam entering the pump.

Fig. 4 is an illustration of this type. It will be seen that the path of the steam follows an easy curve, it being advisable to avoid baffle plates and sudden changes of direction as much as possible. Note should be taken of the generous size of the steam dome at the top of the condenser, obviating air-pockets and distributing the steam easily without the need of directing plates. Small, but important, points in manufacture are: (1) Ferrules which do not allow "creeping" of the tubes. (2) Avoidance of "expanded" tubes. (3) Ample thickness of the tube plates. (4) Staying of the tube plates.

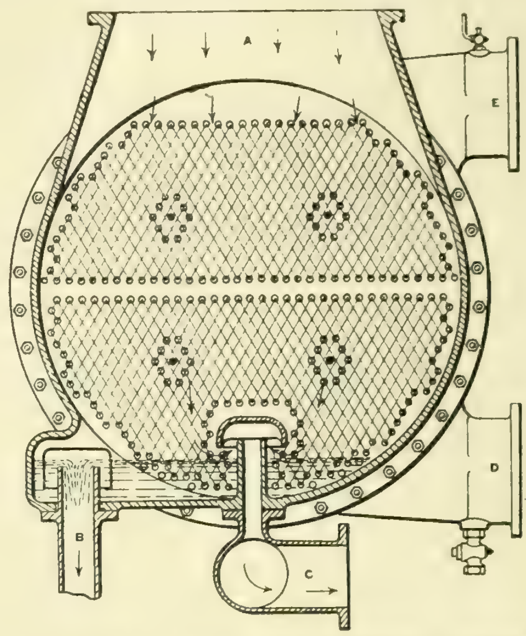


FIG. 5. DIAGRAM OF AN OLDER TYPE OF SURFACE CONDENSER.

A, steam inlet; B, condense outlet over weir; C, air-pump suction; D, cooling water inlet; E, cooling water outlet.

(5) External joints between tube plates, condenser body, and water-boxes.

This last point is very important, as any leakage in the junction between the water-box and tube plate will be to atmosphere and not into the vacuum space, and is, therefore, immediately detected. With the condenser as shown in Fig. 4, having a water velocity of over 5ft. per second, effective condensation can be obtained commercially for land practice at the rate of 8lbs. to 15lbs. per square foot, depending on the degree of vacuum required. The official test at Burnley Corporation electric light station, shown in Table I., is an example of a plant of this type. It will be seen here that with a vacuum of 28·9in. condensation was obtained at 9·4lbs. per square foot. A few years ago this would have been considered very unwise, if not impracticable. In this case the water flows at about 7ft. per second, passing four times through the condenser.

Table II. gives results obtained at the official test of a condenser for the East Indian Railway Company. This condenser was designed for 45,800 lbs. of steam per hour, 26in. vacuum, 2,800 galls. per minute of circulating water at 85° Fah., transmission 435 B.Th.U. per square foot per degree mean temperature difference. The readings give a mean transmission of 639 B.Th.U. The vacuum efficiency in readings 3 to 6 fell off, as by an oversight the condensed steam was allowed to rise a few inches in the condenser, by over-throttling the

extraction pump discharge which was controlled by a sluice valve to give the guaranteed head. The effect of this was similar to a weir in the bottom of the condenser. It will be seen in reading No. 7 the efficiency was rising again. Fig. 5 shows an older type still largely made by British manufacturers.

Table II. *The East Indian Railway Company.*

Extract from Official Test on the Surface Condenser.

Reading.	V.	T_1.	T_2.	T_3.	T_4.	T_5.	δ	S.	k.	η.
1	27·52	69·5	100·5	109	102	85·5	20·2	48,600	584	98·5
2	27·17	76	105·7	113·5	109	98	18·9	46,400	597	98·7
3	26·66	79·8	112·6	119	110·5	107	18·1	48,200	650	97·5
4	26·18	84·5	116·5	123·5	108	115·5	18·65	48,500	632	95·5
5	25·64	88·1	121·9	128·5	108	124	18·65	51,200	666	93·7
6	25·2	93	125·5	132·5	110·5	129·3	18·78	48,500	625	92
7	24·5	100·4	129·7	137	132	135·3	18·15	53,600	720	97

V = Vacuum, inches of mercury (Bar. 30in.).
T_1 = Inlet cooling water temperature, deg. Fah.
T_2 = Outlet cooling water temperature, deg. Fah.
T_3 = Theoretical temperature of steam at inlet to condenser, deg. Fah.
T_4 = Condensed steam temperature, deg. Fah.
T_5 = Air-pump suction temperature, deg. Fah.
δ = Mean temperature difference ($T_3 = T_1$, *see* Appendix, page 39).
k = Transmission in B.Th.U. per square foot per deg. Fah., mean temperature difference.
η = Vacuum efficiency per cent.

By far the most important factor that has to be considered in the rate of transmission of heat from the steam to the cool-

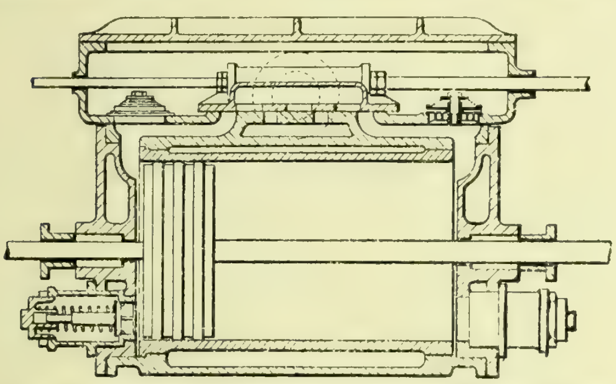


Fig. 6.—Diagram of a Reciprocating Air-pump Cylinder, with automatic discharge and relief valves.

ing water is unfortunately one which has often been much neglected, namely, the absolute partial pressure of air in the condenser. Many people not intimately concerned with the problem of condensation think that the only reason for lowering the partial air pressure in condensers is to reduce thereby the total pressure. A most important point, however, is that the air, being admittedly a bad conductor of heat, should be eliminated as far as possible for this reason also. If this is not done, a certain proportion of the surface near to the air pump suction becomes "air-logged," and little condensation takes place at that point, the surface being wasted. It must, however, be remembered that the distribution of air throughout the condenser is not equal, which affects the results of experimenters with small apparatus who have given many admirable papers on this subject. It is obvious, in any case, that an air pump is necessary that will deal efficiently with air at a very low absolute pressure.

The next point of importance is vacuum efficiency. It is obvious that the hotter the condensed steam is when returning as feed water, the higher will be the overall thermal efficiency of the plant. This point is dealt with more fully under the heading "Auxiliaries." With a good system of departmental drainage a vacuum efficiency of 100 per cent. can be obtained; indeed, Prof. Weighton, in his experiments at Armstrong College, Newcastle-on-Tyne, claims to have exceeded even 100 per cent., probably owing to the vacuum being measured at a point remote from the condensed steam. The author is, however, of the opinion that if serious loss of vacuum is to be avoided in the condenser between the exhaust inlet and the air-pump suction, as straight a flow of steam as possible is desirable, and that departmental drainage, which involves baffle plates, is not to be recommended,

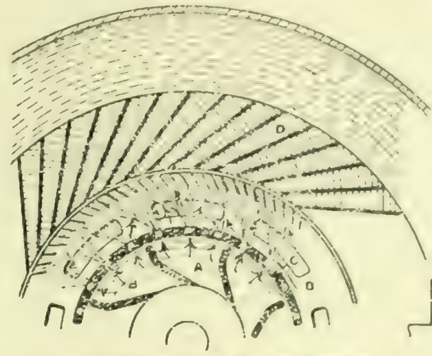
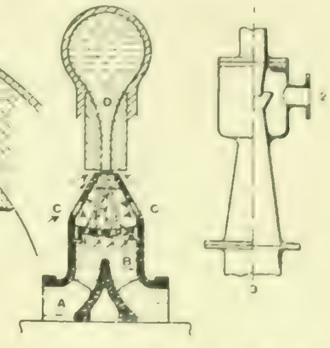


Fig. 7.—Diagram of Rotary Spray Air Pump.



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except to a very limited extent. Referring again to the Burnley tests, it will be seen that a vacuum efficiency of 98·6 per cent. was obtained, without any special arrangement of steam baffles. This is due to the Leblanc air pump, which will be described later.

A condenser designed for moderately high transmission has usually three or four water passes, to obtain the necessary velocity without undue length of tubes between plates. This means it is possible to obtain fairly short tubes, which are easily cleaned, and this is a great advantage. The cost of renewals is also lower, as the number of tubes to be replaced will be approximately the same, whilst their length is shorter; moreover, there is greater freedom from troubles due to "sagging" and vibration. It will now be seen that the performance of a surface condenser for any given set of conditions does not necessarily depend on the number of square feet of surface it contains, but that design and efficiency of air pump play a most important part.

Air Pumps.—It has already been shown that a high efficiency is impossible without a first-grade evacuator. The Hon. Sir Charles Parsons was the first to take a practical step towards solving the problem, when he introduced his vacuum augmenter. It is not intended to describe this well-known invention, but note should be taken that it absorbs from 1 to 1·5 per cent. of the main steam consumption of the turbine

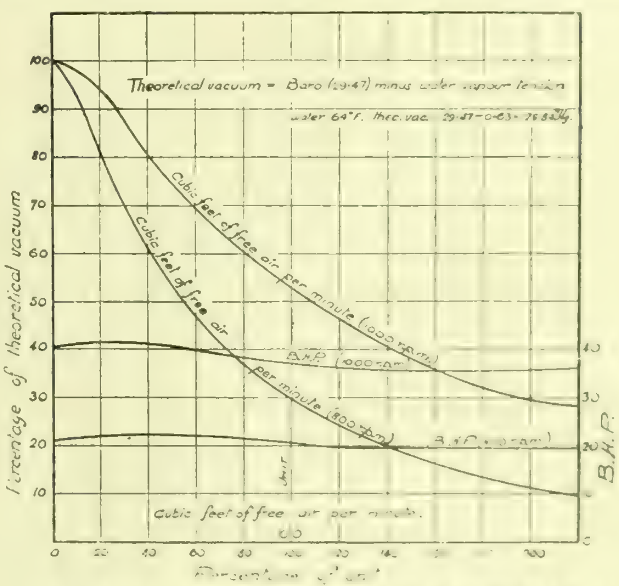


Fig. 9.—Test on Rotary Air-pump of Similar Design to Fig. 7.

at full load, and, in calculating the relative over-all efficiency of different types of pumps, this fact should be taken into consideration; also there is the additional cost of the auxiliary condenser

Excellent results can be obtained by use of a dry piston

pump working with an equalising valve. The use of such valves was a great advance on previous practice; but as the efficiency of the pump depends on very fine clearances any wear on the pistons and valves rapidly decreases the volumetric efficiency, which some makers claim to be as high as

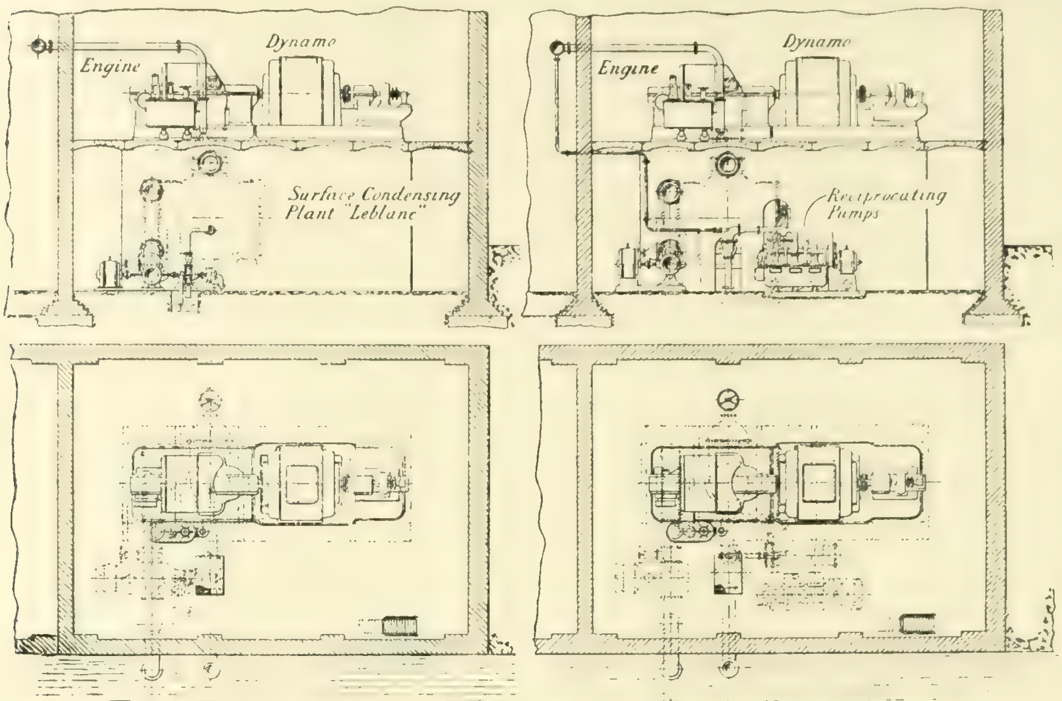


Fig. 10. Space Occupied by Surface-condensing Plant (Leblanc) and by Reciprocating Pumps

98 per cent. Fig. 6 is a common type of dry air pump. It will be observed that, in addition to the slide valve, there are at least two automatic discharge valves and two relief valves. Great care must be taken with the dry piston pumps to eliminate moisture as far as possible from the cylinders; the percentage carried over with the air should not exceed 0·15 to 0·3 per cent. if trouble is to be avoided.

Good results are also obtained with multiple cylinder wet air pumps; one or more cylinders, being flooded with cold water to reduce the vapour tension, are used as an air pump, and the other removes the condensed steam at a higher temperature. This type also suffers, although to a less extent, from the disadvantages of valves which require constant attention and renewal.

Rotary Air Pumps.—With the object of obtaining greater simplicity, while retaining all the advantages of reciprocating pumps and augmenters, various rotary and water ejector pumps have been developed during the last ten years, nearly all of them an evolution of the Körting ejector condenser, which was one of the earliest forms. The Leblanc pump was the first working rotary pump, and all later types follow the same general principles, except the Kolb rotary condenser, which never gave satisfaction in practice. Then came a rotary pump in which water was discharged at a high velocity through a number of rotary converging nozzles. Such a pump is illustrated diagrammatically in Fig. 7.

Pressure is generated by centrifugal force in the central chamber A, which is rotated at a high speed. This pressure is converted into velocity through the converging nozzles BB, which are usually arranged in pairs, the action being similar to that of an old-fashioned gas burner, the resulting water spray taking a fan formation. These fan-shaped jets entrain air which is drawn in through the slots CC. The mixture is discharged through a series of suitably arranged guide blades into the diffuser D, as shown in the illustration.

Fig. 9 shows the results of a test on a pump of this type of a very large capacity, suitable for 100,000lbs. of steam per hour, with a vacuum of 27·4in. It will be observed that the brake horse-power is practically constant for all loads. This is claimed to be an advantage, but in the author's opinion it is the reverse, the efficiency being necessarily bad at light loads. A pump of this type, however, only removes a small weight of air per brake horse-power under normal working conditions. It is obvious that this design can never be efficient owing to the loss of kinetic energy in the spraying nozzles.

A simple type of pump is shown in Fig. 8. The water jet or jets remove the air by ejector action. Here again the expanded volume entrained is very small, often less than twice the volume of water. Still another recent development consists of a combination of a steam augmenter and water jet. The author is unable to give figures of the working of this plant, as there are not many in operation, and no results had been published that the author was aware of when this paper was written, but it would be interesting to know the makers' guarantees on weight of air dealt with for a given power, including the necessary steam reckoned at 10lbs. per brake horse-power.

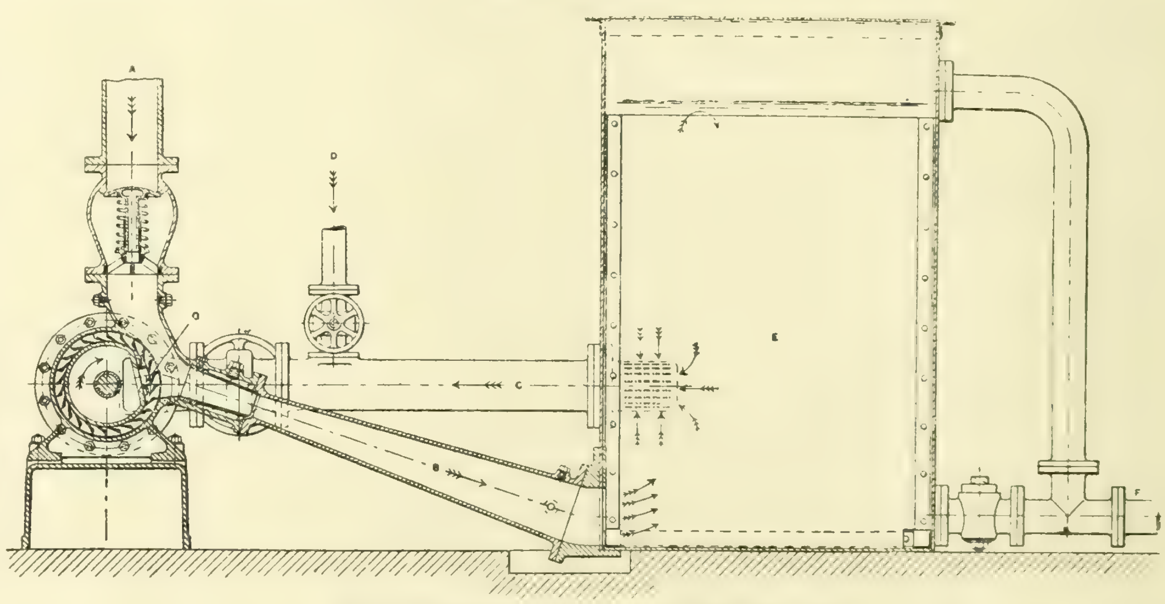


Fig. 11.—Diagrammatic Section of Air Pump and Tank

A, air inlet; B, diffuser and water outlet; C, water inlet; D, valve for filling the tank; E, tank; F, overflow; G, water guide nozzle.

Latest Developments in Rotary Pumps.—Finally we come to the Westinghouse Leblanc dry air pump. This pump has undergone many improvements since it was originally brought out by Prof. Leblanc, and its original faults have been found out by constant experiments and world-wide experience, and eliminated. The changes consist mainly in alteration to the shape of the blades and proportion of the cones, and the points of difference are so dependent on knowledge gained

by experiments, and in many cases so apparently trivial, that it is outside the scope of this paper to describe them.

The latest designs of the Westinghouse-Leblanc pumps will remove much more air per brake horse-power under similar working conditions than any other rotary pump. One peculiarity of this and of similar rotary pumps is that the expanded volume removed increases as the absolute air pressure decreases, the contrary being the case with reciprocating pumps. A great advantage is that the working medium of the pump being at a far lower temperature than the condensed steam, the air is cooled and considerably reduced in volume before being removed. In comparing expanded volumes in various types this fact must be taken into account, which can easily be done by specifying the weight of air instead of the volume. A further advantage of the Leblanc pump is that, to save space and complication, it can in many cases be direct coupled with its extraction pump to a circulating pump running at the same speed without the use of gears, the whole set being driven by a motor or small turbine,

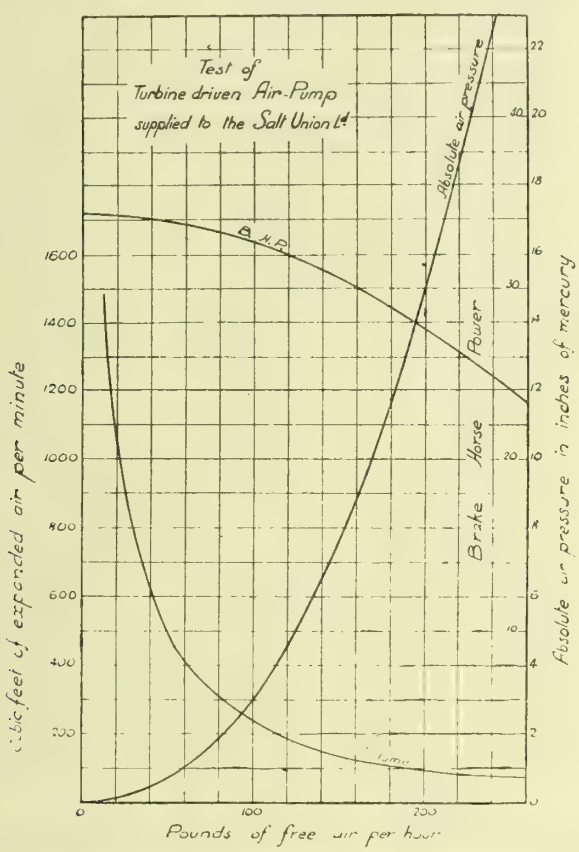


FIG. 12.—TEST ON AIR PUMP (WESTINGHOUSE-LEBLANC) ARRANGED AS IN FIG. 11.

Fig. 10. In the latter case, as a good steam consumption cannot be attained on so small a machine, when running condensing at a suitable speed and with a simple design, it is usual to exhaust above atmospheric pressure, either into a stage of the main turbine or to a feed-water heater. A high overall efficiency can be obtained in this manner. Furthermore, the Leblanc pump in certain cases can be used as a combined air and extraction pump without reducing its efficiency.

Fig. 11 is a diagrammatic representation of the method of operation of the air pump. The particulars are as follows:—

The pump does not take its working fluids from a seal well below its axis as in the older types, but from the tank E with its water level above C. The advantage of this arrangement is that should the vacuum fall for any reason the pump remains primed, and on the leakage being stopped it picks up again without attention. Supposing that the casing is full of water from the tank E, the motor or turbine is started and the wheel revolves in the direction of the arrow. The centrifugal force imparted to the water forces it out through the cone B until the case is empty. This creates a vacuum in the casing, and more water is drawn in through the guide nozzle G. This water is cut off in a series of thin sheets, about 0·2in. thick, which are hurled at a velocity approaching 130ft. per second through collecting cones into the diffuser B. Each sheet of water carries with it a layer of air, the [illegible] mixture being discharged back to the tank E, where the air is separated from the water by a series of baffles between the

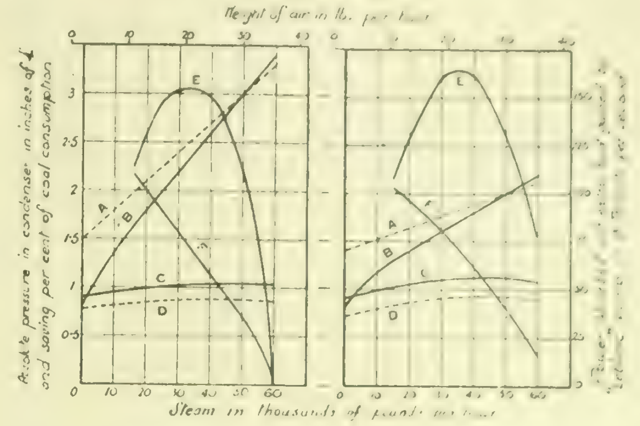


FIG. 13. FIG. 14.

A, absolute pressure in condenser with "wet piston" pump; B, absolute pressure in condenser with a "Leblanc" pump; C, power absorbed by "Leblanc" pump; D, power absorbed by "wet piston" pump; [illegible] gain in B.Th.U.'s obtained with "Leblanc" pump; F, [illegible] coal consumption saved with "Leblanc" pump.

discharge and suction of the pump. Fig. 12 shows a test under these conditions showing that the pump is effectively removing air even at little above atmospheric pressure. It is interesting to note that with decreased vacuum the horse-power also decreases.

It has been said against the Leblanc pump that it absorbs more brake horse-power than its reciprocating rivals. This is undoubtedly true under normal conditions for both types when the plant has to maintain a fairly low vacuum, though under equal conditions of hot-well temperature it is not the case. It will be noticed that condenser builders who use reciprocating air pumps usually advocate a weir in the bottom

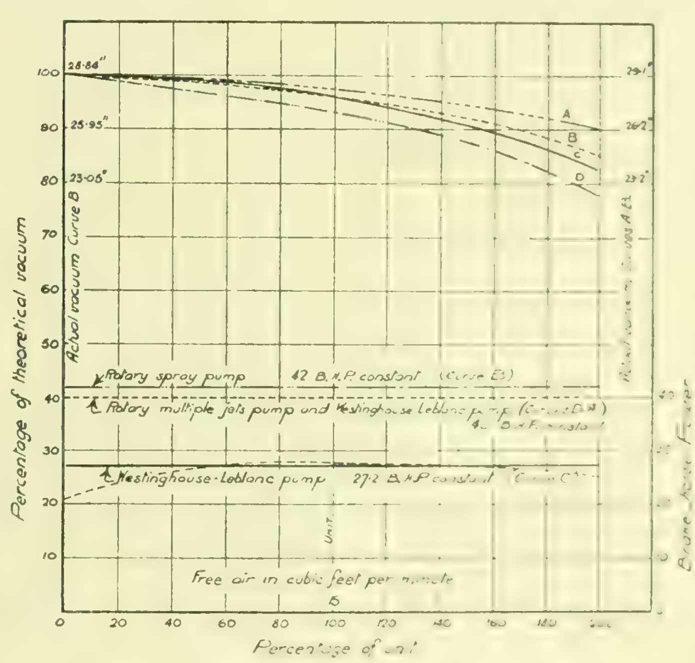


FIG. 15.—TESTS ON VARIOUS TYPES OF ROTARY PUMPS.

Barometer during test of rotary pump [illegible] Hg.; [illegible] 64°F. corresponding to a water vapour tension of [illegible] Hg.; [illegible] 28·84"Hg.; Barometer during test of Westinghouse-Leblanc [illegible] Hg. Temperature of water used 68°F. [illegible] 0·68"Hg.; Theoretical vacuum 29 [illegible] Hg.; Curve A, [illegible] Westinghouse-Leblanc pump, absorbing [illegible] B.H.P.; [illegible] B [illegible] with rotary spray pump, absorbing 42 B.H.P.; Curve C, [illegible] Westinghouse-Leblanc pump, absorbing 27·2 B.H.P.; Curve D, [illegible] obtained with rotary multiple jets pump, absorbing [illegible] B.H.P.

of their condensers to submerge 2 to 3 per cent. of the tubes, with the object of reducing the hot-well temperature to a point at which the air pump can operate on favourable brake horse-power terms with the rotary pump. (See Fig. 4.) A moment's consideration of overall efficiency will expose the false economy of this.

With a 28·8in. vacuum we know that the wet air pump

has a vacuum efficiency of about 96·5 per cent., and therefore requires a hot-well temperature about 80° Fah., which is frequently obtained by means of the weir, while the Leblanc pump will work with 94° Fah., an advantage of 14° Fah. over the piston pump. Now an increase of 14° Fah. on the feed-water temperature means an approximate gain on coal consumption of

$$100 \times \left(\frac{94-80}{1193-80}\right) = 1\cdot 25 \text{ per cent.}$$

with steam at 150lbs. boiler pressure. From this gain must be deducted the percentage lost in extra power for driving the pump, leaving a balance in favour of the Leblanc of 1 per cent. on the overall efficiency. In addition there is the decreased cost of a smaller condenser due to the absence of submerged tubes, less circulating water and simplicity of design and operation, there being no valves or reciprocating parts.

Figs. 13 and 14 show graphically the relative power absorbed by a Leblanc rotary air pump, including rotary hot well pump, delivering to 10ft. external head, compared with a reciprocating wet air pump of good design. In Fig. 13 full load has been taken at 27in. vacuum, and in Fig. 14 at 28in. vacuum. The power has been given in B.Th.U. for the sake of simplicity, an overall efficiency of 20 per cent. being assumed. The other curves give the respective total absolute pressures in the condenser, the total heat returned by the rotary pump in the hot well in excess of that returned by the piston pump, the net gain in B.Th.U. and the overall gain in coal consumption, assuming that live steam at 100 per cent. efficiency be used to raise the hot well temperature before entering the economiser, in the case of the piston pump.

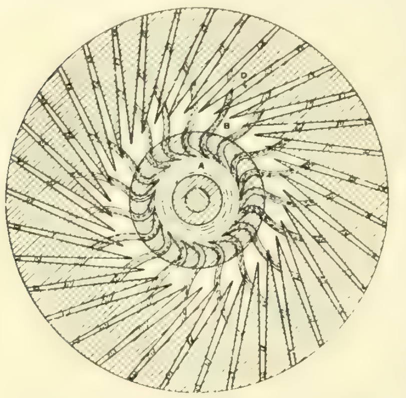


FIG. 16.—DIAGRAM OF ROTARY JET PUMP.

Pressure is generated in the revolving chamber A, and a thin stream of water is projected across the chamber B extraining air which is compressed in the passage D up to atmospheric pressure.

In calculating the net gain in B.Th.U., allowance has been made below full load on the condenser for the decreased steam consumption for equal power outputs due to the higher vacuum maintained by the Leblanc pump; this decrease has been taken as 5 per cent. mean between 27in. and 28in. vacuum and 6 per cent. between 28in. and 29in. vacuum. In Fig. 15 curve C shows a test on a Leblanc pump superimposed on the test of the rotary spray pump. The pumps are of approximately the same capacity, and it will be seen that the power taken by the Leblanc is considerably less than the other, namely, 42 b.h.p. This variation in power is, of course, obtained by regulating the quantity of water passing through the pump to suit the load. If the controlling valve is left set for full load conditions, the power will, of course, remain constant at 27 b.h.p. The other curves, D and A, are for a less known (in this country) type of rotary pump, Fig. 16, which needs no detailed description, and for a Leblanc pump of approximately the same brake horse-power as the rotary spray pump.

Finally, the author would recommend that intending purchasers of air pumps would do well to insist on makers guaranteeing the weight of air to be removed* (not expanded volume, which means nothing), the total power absorbed, including steam jets at (say) 10lbs. per brake horse-power, and the temperature of the condensed steam as delivered to the pump from the condenser, not as it leaves the hot well pump, the real efficiency, of course, depending "on how little" heat is extracted from the condensed steam and imparted to the circulating water and lost therein.

(To be continued.)

* Average 13lbs. of air per 22,000lbs. of steam for surface condensers in conjunction with turbines, and 36lbs. per hour for the same steam from engines. For jet condensers, the air in the water must be added, which may vary from 2·4lbs. to 5lbs. per 10,000 gallons of water. See Fig. 25 in appendix IV. to be given later.

TWO-STROKE CYCLE CONTINUOUS-COMBUSTION OIL ENGINES FOR SHIPS.

Two arrangements showing the application of two-stroke cycle continuous-combustion internal-combustion engines to the propulsion of ships, are shown in the accompanying illustrations. They have been designed and patented by Messrs. Sulzer Bros., of Winterthur, and have two or more driving engines, in which each propelling engine drives one or more pumps which supply air thereto within given limits of load, separate auxiliary motors being also provided for supplying additional air for scavenging, charging, starting, or the like. In the arrangement shown in Fig. 1, the main and auxiliary engines are divided in groups, each group being in a water-tight compartment and the groups being so arranged that the auxiliary engine of an after group is arranged above the propeller shaft driven by the engine forward thereof. In the arrangement shown in Fig. 2, the main engines are disposed in one compartment and the auxiliary engines in a separate adjacent compartment, and the delivery pipes of all the pumps of the main, as well as the auxiliary engines, are capable of being connected together or shut off by means of valves or cocks, the suction pipes being similarly arranged.

In the construction shown in Fig. 1, the machinery is arranged in two water-tight compartments A and B, the main engine C having six cylinders. The charging air pump D is directly connected to the engine and a compressed-air pump which may be used for starting some other engine, reversing, or operating auxiliary machines, may also be directly connected thereto if desired. The auxiliary engine E is arranged in the same water-tight compartment A and supplies additional scavenging and charging air, as well as compressed injection-air, compressed starting air, &c., to the main engine C. The charging air pumps have a suction pipe F and a discharge pipe G, opening into the receiver H of the main engine. The exhaust pipes J and K of main, as well as of auxiliary engine open into a joint chimney L.

In the water-tight compartment B is arranged a main engine M with six cylinders, with a directly connected charging air pump N. The main engine drives the propeller shaft O. In this compartment, as in the compartment A, there is further arranged an auxiliary engine Z for supplying scavenging and charging air and high-pressure air for reversing, starting, atomising, and injecting the fuel, &c. The charging air pumps are provided with a suction pipe P, and a discharge pipe Q, opening into the receiver R of the main engine M. The exhaust pipes S and T of the engines arranged in the compartment B are led into a funnel U.

As will be seen from Fig. 1, the propeller shaft O is arranged in such a low position that the auxiliary engine E can be arranged directly above it. The receiver H of the main engine C is connected by a pipe V to the receiver R or air supply pipe Q, of the other main engine M. The two receivers H and R can be connected to or disconnected from each other by means of a stop cock W, so that in the event, for instance, of one auxiliary engine failing, the charging air could be supplied from the other auxiliary engine. The auxiliary engine E drives a pump X and the auxiliary engine Z a dynamo Y.

In the construction shown in Fig. 1 each propeller-driving engine drives an air pump for supplying scavenging and charging air, as well as compressed air for starting and reversing, for a limited power of the main engine, whilst separate therefrom, in another water-tight compartment, are arranged auxiliary engines which supply additional scavenging and charging air as well as compressed air for starting and reversing. In this arrangement the hull of the ship has mounted within it two propeller shafts, which are each driven by a two-stroke internal-combustion engine, A and B respectively.

The propeller-driving engine A comprises six cylinders, and has a scavenging and charging air pump C directly connected to it, and also a high-pressure air pump D. The cylinders receive their scavenging and charging air through the pipes E, and discharge their exhaust gases into the pipe F leading into the uptake G. The propeller-driving engine B also comprises six cylinders, and a scavenging and charging air pump H, directly connected to it, and has a high-pressure air pump I. The cylinders receive their scavenging and

charging air through the pipes J, and discharge their exhaust gases into the pipe K leading into the uptake G. The compartment containing the two propelling engines A and B, is closed by two water-tight partitions.

The two auxiliary engines L and M are arranged in a separate compartment as shown. Each of these auxiliary engines comprises two engine cylinders, and each of these drives a scavenging and charging air-pump cylinder N and O. The rods of this charging air pump, each drive by means of a balance lever, a two-stage high-pressure air pump P. These high-pressure air pumps deliver their charge through pipes into the high-pressure air reservoirs Q. The high-pressure air pumps D and I also discharge into the high-pressure air reservoirs Q, these pumps being directly connected to the propeller-driving engines. The compressed air supplied by the high-pressure air pumps D, I, and P can be used both for starting and reversing the internal-combustion engines, atomising, and injecting the fuel, and also for engines worked by compressed air, for driving dynamos, pumps, hoists, &c.

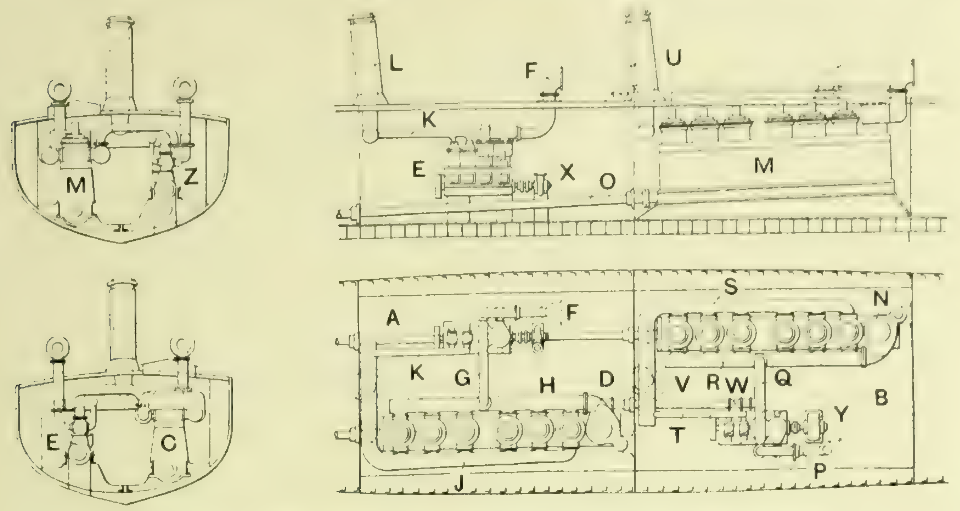


FIG. 1. TWO-STROKE CYCLE CONTINUOUS COMBUSTION OIL ENGINES FOR SHIPS

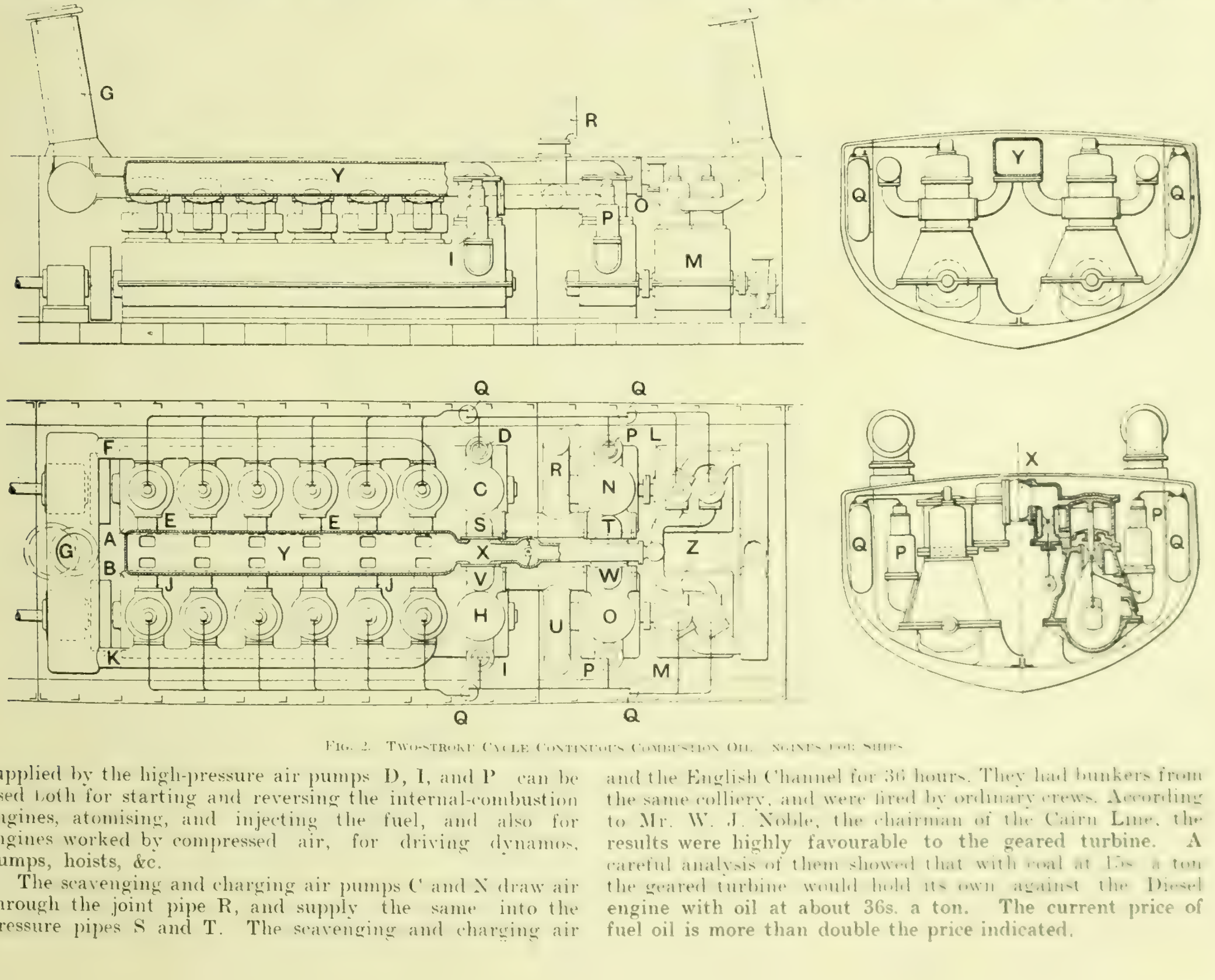


FIG. 2. TWO-STROKE CYCLE CONTINUOUS COMBUSTION OIL ENGINES FOR SHIPS

The scavenging and charging air pumps C and N draw air through the joint pipe R, and supply the same into the pressure pipes S and T. The scavenging and charging air pumps H and O draw in the air through the joint pipe U, and convey the same into the pressure pipes V and W. All the pressure pipes S, T, V, and W, deliver into a joint pressure chamber X, in which is arranged an adjustable valve, by means of which the pressure chamber of the auxiliary engines can be separated from that of the main engine. This valve is, for instance, closed when the quantity delivered by the scavenging and charging air pumps C and H, directly connected to the propeller-driving engines A and B, is sufficient for the working of the latter. The scavenging and charging air passes from the pressure chamber X into the receiver Y, which is used jointly for both propeller-driving engines. From the receiver Y the scavenging and charging air passes through the pipes E and J, into the engine cylinders. A second branch of the pressure pipe X leads into the scavenging and charging air pipe Z of the auxiliary engine cylinders. By means of a valve formed in the pipe Z leading to the auxiliary engines, the supply to the same can be regulated or stopped in any desired manner. The auxiliary engines may be used at the same time for driving other pumps, electrical or other machinery.

Trials of a Geared Turbine Vessel.—For the purpose of trying the cargo steamer "Cairnross" fitted with geared turbines, the "Cairnrowan," a similar ship, but driven by means of triple-expansion engines, was got out, and the two were recently run side by side at full power in the Bristol Channel and the English Channel for 36 hours. They had bunkers from the same colliery, and were fired by ordinary crews. According to Mr. W. J. Noble, the chairman of the Cairn Line, the results were highly favourable to the geared turbine. A careful analysis of them showed that with coal at 15s. a ton the geared turbine would hold its own against the Diesel engine with oil at about 36s. a ton. The current price of fuel oil is more than double the price indicated.

THE REACTIONS OF THE PUDDLING PROCESS.*

BY PROF. THOMAS TURNER, M.SC.

It is now more than half a century since the introduction of the Bessemer process startled the civilised world and threatened the entire extinction of the trade in malleable or wrought iron. The successful development of the new process occupied some years, and taxed the energies and the skill of so great an inventor and so keen a business man as Sir Henry Bessemer. For nearly 20 years the older process suffered comparatively little from the attack of its young and vigorous rival; but the gradual introduction of mild steel for rails, plates, wire, and guns gave such a shock to the iron trade that when the bad times of the later 'seventies came the whole iron industry was again threatened with extinction. To-day we see a most remarkable change in the relative position of the two processes. Bessemer steel is now threatened by its newer open-hearth rivals, its annual output is diminishing, and its continuation is held by some competent observers to be problematical. The wrought-iron trade, on the other hand, after having shrunk to relatively insignificant proportions, now shows signs of permanency, and even of expansion, which was certainly unexpected only a few years ago. At the end of 1912 there were in the South Staffordshire and North Worcestershire districts, 32 firms engaged in the production of puddled iron. These firms operated 661 puddling furnaces, and employed a total of about 10,000 hands, while the trade was in a very prosperous condition. During the last year or two the demand for really capable puddlers has exceeded the supply, and there is a call for younger men to train for the work.

It may be well to glance for a few minutes at some of the causes which led to these changes. The reason for the adoption of steel are obvious and clear. As compared with malleable iron, steel could be produced in larger masses, with greater uniformity of texture, with less labour, and at a greatly diminished fuel consumption. It also possessed a higher tensile strength and limit of elasticity, while its enormously increased resistance to wear rendered it invaluable for rails, wheels, and many similar purposes. For such applicatains no enthusiast would be so bold as to dream that wrought iron can ever replace steel.

On the other hand, it must be acknowledged that wrought iron has certain properties which are largely responsible for the fact that this variety of material is to-day in increasing demand. Amóng these properties are the readiness with which it can be welded or otherwise smithed, its trustworthiness under certain kinds of shock,† and its power of resisting atmospheric action. In consequence for chains, nails, wire, sheets, rivets, bolts and nuts, gas pipes, and many similar purposes malleable iron is still preferred in many cases. A distinct demand has also arisen for ships' fittings and for colonial purposes, where the loss of value due to corrosion is so serious with certain kinds of steel. While it is true that steel can be made to weld regularly and perfectly, and that sometimes it stands the weather as well as wrought iron, still in such cases it may be pointed out that wrought iron is not said to weld as well as steel or to stand the weather as well as steel. On the contrary, it is claimed for a superior piece of steel that it welds like wrought iron, or rusts as little as wrought iron, as the case may be, thus showing that after all our standard of comparison for such purposes is not steel but good malleable iron. For further amplification of this branch of the subject, reference may be made to two excellent papers recently read by Mr. H. Pilkington, one before the West of Scotland Iron and Steel Institute, and the other, a few weeks ago, before the Staffordshire Iron and Steel Institute, at Dudley. These two papers are very suggestive and full of useful information.

Though the continued demand for wrought iron is thus due to the qualities of the material itself, there are, of course, several other causes which have contributed to this result. In the first place, when the greater demand for steel arose there were existing mills and forges which if stopped were only valued at breaking-up prices. Many ironmasters naturally clung to their trade as long as possible, and of these the most capable and the most favourably situated survived. There was also the fact that certain kinds of pig iron which were admirably suited for puddling are not so well adapted for steel-making by any of the larger processes. So long as the argillaceous and the brown iron ores of this country are available, so long shall we also have pig iron which will be suitable for use in the puddling furnace.

The process being thus with us, and with a probability of increased activity, it may be well to consider how far it may be possible to improve upon our present procedure and so increase the output, lower the cost, or improve the quality of the product. It may at once be frankly confessed that the hope of any revolutionary change is remote. The process has been so long with us, has stood such fierce competition, and attempts at drastic alterations have been so often made, and so often abandoned, that it is probably by careful attention to details rather than by changes in principle that the best results will be obtained.

There are in all businesses certain commercial considerations which can only be mentioned, but not discussed, in detail here. Questions such as the selection of the site, the general design of the establishment, the supply of raw materials, the quality, cost, and organisation of labour, the facilities for marketing, and the methods adopted for keeping in touch with and satisfying customers, apply to all businesses which are conducted on a large scale, and not less, in these days of competition, to the wrought-iron trade.

The attention of the metallurgist is concentrated rather upon what goes on inside the works, and the more commercial aspects are dealt with by the commercial staff, whose training is often less expensive, but whose remuneration is not infrequently on a higher scale. Among the questions which confront the metallurgist are the quality of the pig iron employed, the quality and consumption of fuel, the character of the fettling, the most suitable size and shape of furnace, the reactions which take place while the impurities of the iron are being removed, the losses during the conversion, and the quantity and quality of the iron and the tap cinder. He then has to follow the puddled ball through all its stages of hammering, rolling, piling, reheating, and finishing, until at length it has been tested and is ready for sale. The mere enumeration of these questions and processes indicate how wide a field there is for careful observation and discussion, and it is obvious that only a very limited portion of the field can be covered in any single paper.

About twenty years ago I contributed to the Iron and Steel Institute and to the Staffordshire Iron and Steel Institute certain papers dealing with the theory of the puddling process, and these were, with additions and alterations, afterwards incorporated in my "Metallurgy of Iron." At that period the pyrometer and the microscope were only beginning to be applied to metallurgical problems, and there was little accurate knowledge of the physical constants of the materials used by the iron and steel maker. It may be well now to place on record some of the results which have since been obtained, as these preliminaries will be of use for reference, and will be of great assistance in our further discussion of the problems to which we hope to direct attention.

Turning first to the metal used, it will be remembered that it was formerly customary to give the melting point of pure iron as being 1,600° C. The careful determinations of Carpenter and Keeling gave the lower figure of 1,505° C. on the thermo-couple scale, and that figure is now generally accepted. On adding carbon to the iron, it is well-known that the metal becomes much more readily fusible. The lowest melting point, or eutectic, of the series is with about 4·25 per cent. of carbon, and is at about 1,130° C. Such a material can only be produced when a very high temperature has been employed. In ordinary pig iron the carbon usually varies between about 3 and 3·6 per cent., and the melting point is consequently in the neighbourhood of 1,250° C. The presence of silicon, or of phosphorus, makes the pig iron more readily fusible and more fluid when melted. But under ordinary circumstances pig iron which contains, say, 3 per cent. of silicon, requires a somewhat higher temperature in

* Paper read before the West of Scotland Iron and Steel Institute Jan. 11th, 1913.

† Puddled iron and extra-soft steel, which have nearly the same composition (apart from the percentage of manganese, which ranges between 0·05 and 0·4 per cent.), and which have also the same mechanical constants, show a marked difference as regards the length of time required to effect rupture (by vibratory movement); puddled iron resists much longer than extra-soft steel (Boudouard; Proceedings of the International Association for Testing materials, 1912, page 498)

order to melt it than does a rather purer material. The reason for this is that when part of the total carbon is replaced by silicon the loss of carbon raises the melting point somewhat more rapidly than the gain in silicon causes it to fall. The net result of the addition of silicon is, therefore, usually not to lower, but to raise the melting point of pig iron. If phosphorus is present the melting point is lowered, owing to the formation of an iron-carbon phosphorus eutectic, which melts at about 950° C. This phosphorus is, however, not uniformly distributed through the whole solid metal, but in the case of grey iron is met with in separate enclosures or segregations, and as a result a phosphoric pig iron, when slowly melted, has a tendency to part with some of its phosphorus by a process of sweating or liquation. This recalls the view expressed by Dr. Percy, before the theory of puddling was so fully examined—namely, that the phosphorus was removed by liquation. This view is no doubt partly true, though other things have to be remembered before a complete explanation can be supplied.

Viewing next the infusible oxides with which our furnace may be lined, or our firebricks made, it may be recalled that the usual definition of a refractory material at present is that it is a substance which can successfully resist a temperature of 1,600° to 1,650° C. Thus magnesia melts at 2,250°, lime at 1,900°, alumina at 1,880°, and silica at 1,725°. Judged by this standard, the firebricks are refractory, as they soften at about Seger cone 30, or, say, 1,700° C., but the oxide of iron used for fettling, or making up the sides and bottom of the working part of the furnace, is scarcely a true refractory. According to Kohlmeyer, ferric oxide (Fe_2O_3) melts at 1,565° C., and magnetic oxide (Fe_3O_4) at 1,527°. The temperatures of the puddling furnace are, therefore, comparatively moderate.

Though the puddling processes are, chemically speaking, the application of a number of oxidising reactions whereby the impurities originally present in the pig iron are removed, the direct effect of the oxygen of the air is relatively small. In fact, atmospheric oxidation must be regarded rather as a source of waste metal than an action to be encouraged or increased. During remelting no doubt a certain amount of metal is oxidised as it is gradually heated and ultimately fused. A still greater oxidation usually occurs during the balling-up stage of the operation, and practically the whole of this oxidation leads to loss of iron.

The fettling of the furnace, so long as it remains hard and infusible, is also without any important action on the metal. The temperature of the furnace when the metal melts is probably about 1,300° C., and during the hottest part of the heat, just before the metal is withdrawn, is probably very little, if any, above 1,400°, and at this temperature ferric oxide is infusible. The most active agent in the purification of the iron is the bath of fluid slag, or cinder, into which the crude metal trickles as it melts, and by which it is covered during the subsequent stages of clearing and boiling.

For many metallurgical purposes a fluid slag may be considered to consist of three separate parts: (1) A fusible portion, usually a silicate, which takes no direct part in the reactions, but may be regarded as a solvent or mother liquor. (2) An active agent which is dissolved by the solvent and thus brought into intimate contact with the metallic or other substance upon which it is required to act. (3) The product of the reaction, which, when non-volatile, accumulates in the cinder until at length a proportion is reached which prevents the proper progress of the reaction. It corresponds with the waste products of a living organism, which, if not removed, ultimately lead to death.

The three parts of puddling cinder are respectively:—

1. The solvent is ferrous silicate 2 FeO SiO_2, which, when pure, melts at about 1,183° C., as determined by Mr. Dixon in my laboratory some years ago. When melted, it is almost as fluid as water; on cooling it gives a very distinct arrest at its solidifying point, and crystallises in dark, semi-vitreous plates which belong to the rhombic system, and which occur in nature as the mineral Fayalite. It contains 70·6 per cent. of ferrous oxide and 29·4 per cent. of silica. In its pure form it is rather too infusible, and much too siliceous to form a good cinder.

2. The active agent is magnetic oxide of iron, which consists of Fe_3O_4, or FeO . Fe_2O_3. One method of preparing magnetic oxide is by heating ferric oxide to its melting point,* when oxygen is given off and magnetic oxide results. In practice, however, it is very seldom that magnetic oxide possesses exactly the composition which corresponds with the formula Fe_3O_4. It may still be attracted by a magnet, or even become distinctly polar, and show its characteristic crystalline form, while the proportion of ferrous oxide varies considerably from that required by the formula. We may, therefore, speak of the active agent which is dissolved in the ferrous silicate by the less definite term of "oxide of iron," it being understood that by this name is indicated a more or less altered form of ferric oxide.

Ferrous silicate can readily dissolve either silica or oxide of iron. The addition of silica gradually raises the melting point and makes the material viscous when hot, and slow setting like a glass. With sufficient silica a dark olive-green bottle-glass is obtained. This has no definite melting point, and gives no arrest on the cooling curve. The addition of oxide of iron first slightly lowers, and then gradually raises the melting point until ultimately the temperature of 1,565 is reached with pure ferric oxide.

It is known from steel works practice that in order to remove phosphorus from the metal the silica in the bath of slag must not exceed 20 per cent., and this limit is probably rather too high for safe working. Since ferrous silicate contains 29·4 per cent. of silica, it is evident that it must dissolve half its weight of oxide of iron, at least, in order to make a satisfactory cinder. Puddling cinder is thus a very strong solution of oxide of iron. This solution coming in contact with iron, when both are in the fluid state, is practically without action on the metal, since a metal cannot reduce its own lower oxide. It does, however, rapidly oxidise the non-metallic impurities—carbon, silicon, and phosphorus, while even sulphur is also removed. Puddling cinder doubtless acts as a carrier of oxygen from the air to the metal, though the extent to which the action takes place has not been carefully determined. Puddling cinder also contains relatively small quantities of lime, alumina, manganous oxide, and other impurities derived from the fettling, and these tend to lower the melting point. Actual determinations in my laboratory, by Mr. Coe, have given a solidifying point of 1,075° C., for tap cinder.

3. The product of the reaction which is present in the cinder is phosphorus, in the oxidised condition, probably as normal triferrous phosphate $Fe_3(PO_4)_2$. Several important researches have been published in reference to the condition in which phosphorus exists in the basic slag from steel making. Dr. Stead has isolated and recognised a tetra-basic phosphate. Tap cinder does not appear to have received the same careful examination; it is found from analysis that the phosphoric oxide does not usually reach 7 per cent., and its presence appears to increase the fluidity of the cinder, though exact information on this point is lacking. If the pig iron used is high in phosphorus it is well to concentrate this as far as possible in that portion of the slag which is first removed, and which usually boils over the fireplace. The removal of the impurities at this stage is economical in fettling, and yields a better ultimate product.

It has been assumed in what has hitherto been stated that the active oxide of iron is wholly dissolved in the slag. There is some evidence that metallic iron can dissolve oxide of iron, though apparently not in large quantity. The subject is now receiving attention at the hands of several investigators, and it may be that the reactions are in part those which take place between iron carbide, silicide, and phosphide, dissolved in the fluid metal, and oxide of iron also soluble in the bath of iron. (Compare Rosenhain, Proceedings of the International Association for Testing Materials, 1912, page 553.)

Before considering the reactions further it may be well to say a few words as to the composition of the pig iron to be employed. Even when the ironmaster has, in his own mind, a definite ideal composition, he is not always able to get exactly what he wants, and is certainly not able always to ensure regularity in character. One advantage of the use

* The dissociation pressure of Fe_2O_3 [illegible] sphere at 1350 deg. Below that temperature [illegible] At 1350 deg. magnetic oxide shows no [illegible] Walden [illegible] Soc. 1908, 30, page 1350.)

of three or four brands of pig iron in a heat is, no doubt, the greater uniformity thus ensured, as it is unlikely that all of them will vary in the same way at the same time. Fortunately the puddling process lends itself to considerable modifications in detail, so as to suit different classes of iron; otherwise it would long have passed away. A typical iron may have approximately the following composition: Carbon, chiefly graphitic, 3·5 per cent., silicon, 1·5 to 2 per cent., phosphorus, 1 per cent., manganese, 0·75 per cent., and other impurities as low as possible.

It is generally a mistake to attempt to puddle with too pure an iron, and this for two reasons. In the first place, the metal costs more to buy, and yields less weight in the furnace. Secondly, it is apt to work "dry," and to be red-short in the subsequent processes, while the bottom of the furnace is apt to scurf. But the improvement due to silicon and phosphorus is only obtained within certain definite limits. With too large a proportion of metalloids the extra time occupied and fettling melted may more than compensate for the initial gain.

Let us now imagine our furnace is hot and properly fettled, and the pig iron is weighed out and ready to be charged. The first step usually is to charge in some shovelsful of cinder, such as the slag obtained from the forge hammer. On this the pig iron is charged, care being taken to place any pigs which have a higher melting point in a position in which they will get the most heat, so that as far as possible all may melt down together. Since the cinder melts at about 1,100°, and the pig iron usually at over 1,200°, it will be found that the cinder is fluid before the iron is melted, and the metal therefore trickles down into a pool of slag. Possibly the phosphide eutectic tends partially to liquate out before the rest of the pig iron melts, but in any case the metal at once comes in contact with a basic liquid rich in dissolved oxide of iron. Much of the phosphorus is at once given up to the slag, but the remainder passes away slowly during the rest of the process. Silicon and manganese rapidly pass out of the fluid metal, and are usually practically gone within 10 to 15 minutes after the whole of the iron is melted. Until the whole is well and uniformly fluid and "cleared," the carbon is not attacked; but when once clearing is completely finished the object is to bring on the "boil" as quickly as possible.

Allowing our minds to picture the meeting of an atom of carbon with the surrounding fluid containing oxide of iron, we see that several things are possible. It might, for example, meet one molecule of ferric oxide, when we should have

$$(a)\ Fe_2O_3 + C = 2\,FeO + CO,$$

and the result would be that one molecule of carbon monoxide would be evolved and burn in the blue jets of the furnace, while two molecules of ferrous oxide would be added to the slag. So far as yield is concerned, there would be no gain of iron, but a loss exactly equal to the amount of carbon removed. On the other hand, our atom of carbon might meet a molecule of ferrous oxide, when we should get

$$(b)\quad FeO + C = Fe + CO$$
$$(56 + 16) + 12 = 56 + 28$$

In this case we should still get the same amount of carbon monoxide, but nothing would be added to the slag, while 12 parts of carbon would add 56 parts of iron to the yield. But since 12 parts of carbon would be lost, the net increase of weight would be 44 parts. Hence each part of carbon removed would take from the fettling and cinder and add to the charge no less than $3\frac{2}{3}$ times its own weight of iron. These equations represent the worst and the best of what may happen. But other actions are also possible, such as—

$$(c)\ FeO.\ Fe_2O_3 + C = Fe + Fe_2O_3 + CO$$
$$(d)\ FeO.\ Fe_2O_3 + C = 3FeO + CO$$
$$(e)\ FeO.\ Fe_2O_3 + 4C = 3Fe + 4CO, \text{ \&c.}$$

Similarly for silicon we may have

$$(a)\quad FeO.\ Fe_2O_3 + 2Si = 3Fe + 2SiO_2$$
$$(b)\quad FeO.\ Fe_2O_3 + Si = Fe + 2FeO + SiO_2$$
$$(c)\ 2FeO.\ Fe_2O_3 + Si = 6FeO + SiO_2, \text{ \&c.}$$

From this it will be seen that as the oxide of iron increases the yield decreases, exactly as was the case with carbon. The reactions with phosphorus are of the same character though slightly more complicated in form, thus

$$(a)\ 5FeO.\ Fe_2O_3 + 8P = 15Fe + 4P_2O_5$$
$$5 \times 232 \quad 8 \times 31 \quad 15 \times 56 \quad 4 \times 142$$

hence 248 of phosphorus reduces 840 parts of iron from the cinder and fettling, or one part reduces 3·4 parts of iron. Subtracting the loss of one part of phosphorus we have that each 1 per cent. of phosphorus adds 2·4 per cent. of iron to the charge. Or we may have

$$(b)\ 5FeO.\ Fe_2O_3 + 2P = 15FeO + P_2O_5$$

in which case 62 parts of phosphorus will use up 1,160 parts of oxide of iron, or nearly 19 times its own weight and add nothing to the yield.

It will therefore be seen that under certain specified and favourable conditions, carbon, silicon, and phosphorus can be removed, and their places taken by a greater weight of iron obtained from the fluid bath of cinder. The ideal condition is by the reduction of ferrous oxide as this contains least oxygen. In this case, after allowing for the loss due to the removal of the non-metallic element itself, 1 part of carbon may add $3\frac{2}{3}$ its own weight of iron, silicon 3 parts, and phosphorus $3\frac{1}{2}$ parts. Or, conversely, these non-metals may be oxidised in such a manner as to use up many times their own weight of oxide of iron, and add nothing whatever to the charge. In practice it may be assumed that we always work under some intermediate conditions, and though some metal should be gained, the quantity never reaches the theoretical maximum.

From a practical point of view the question naturally arises: How far the reactions are under control, and what are the conditions which ensure the best results? An examination of our equations will show that in all cases where there is no iron added to the charge the quantity of oxide of iron, and particularly of ferric oxide, is excessive. So long as other conditions, such as time, remain constant, any excess of ferric oxide diminishes the yield. It also tends to make the cinder less fusible, and the iron dry under the hammer. It may, however, quicken the rate of reaction in many cases. If the total oxide of iron which is present in the cinder during the boil be separately estimated as ferrous and ferric oxide respectively, it will be found that there are in every 10 parts about nine of ferrous oxide and one of ferric oxide. The cinder which is tapped out at the end of the process contains about twice as much ferric oxide, which is in the proportion of about five parts of ferrous oxide to two of ferric oxide. Within these two limits we have the usual working composition.

We have, however, already seen that ferrous silicate dissolves about half its own weight of oxide of iron in the formation of puddling cinder. We may hence assume that, in the first case just mentioned, of the nine parts of ferrous oxide about six were present combined with silica, and three in the free or dissolved condition. The composition of the active oxide of iron would therefore be approximately $6\ FeO\ Fe_2\ O_3$. Similarly, the composition of the active oxide of iron in the second case would be approximately $2\ FeO\ Fe_2O_3$. By thus eliminating the ferrous silicate from the calculation, the difference in composition of the dissolved oxide in the two cases is made more evident, and it will be seen that any explanation, such as was formerly in vogue, based merely upon the reactions of Fe_2O_3, must be misleading.

The practical application of these considerations is that care should be taken when puddling impure irons to provide a sufficiency of readily fusible material rich in ferrous oxide, so as to give a fluid bath of cinder early in the melting-down and clearing stages. Such cinder assists in the rapid purification of the iron, increases the yield, and is the cheapest and readiest means of properly working a charge. If there is a deficiency of cinder in the early stages, more has to be made at the expense of the iron and of the more infusible fettling. The making of cinder in this way leads to waste of time, metal, and fuel, and should be avoided as far as possible.

The presence of a reasonable proportion of non metals in the original pig iron not merely increases the yield of puddled iron, for reasons above given, but also improves the fluidity

of the cinder, and hence the proper working of the charge, and the quality of the product. An all-hematite charge, for example, is unsatisfactory. The metalloids diminish the ferric oxide in the cinder, while the products of the oxidation of silicon and phosphorus also tend to give a slag with a lower melting point than a purer material would possess.

It may perhaps be supposed that if it is good to have 1 per cent. of phosphorus and 2 per cent. of silicon, it may be still more advantageous to have yet larger proportions of metalloids. To this there are very definite limits in practice. It has been already shown that if the suitable proportions are not preserved as between oxide of iron and the metalloids, it is possible to use a great deal of fettling without gaining a single particle of iron. Cinder is also a slow conductor of heat, and a thick covering of slag prevents the iron receiving its proper share of heat. Hence too thick a coating of cinder is not good, particularly if that cinder is being made from the fettling by a "hungry" iron.

A few words may not be out of place in reference to the temperatures of puddling furnaces. In steel making it is known that phosphorus is removed best at relatively low temperatures, and that if the heat becomes too great, the removal of phosphorus may practically cease. In the puddling furnace these conditions do not apply. To one who stands in front of a puddling furnace on a hot, close day, and works a heat of iron, it may appear that the inside of a puddling furnace is a hot place. As compared with the heat of a regenerative steel furnace, or of an electric furnace, the temperature employed in puddling is, even at its maximum, relatively low. The result is that, so far as I am aware, the furnace is never too hot to allow of the removal of phosphorus. On the other hand, it is considered best practice, if good puddled bar is to be obtained from rather inferior iron, to charge in more hammer scale than usual and to work the charge as hot as possible.

However important the chemical aspects of the puddling process may be, in order to obtain proper and economical purification of the original pig iron, many other questions assume equal importance in actual practice. Improvements have been suggested from time to time, and of these some have been of a character which would improve the process altogether off the face of the earth. The inventor was at his busiest when the competition of steel became keen, and hence in the ten years between 1867 and 1876 inclusive patents were issued in Britain alone at the rate of about one every seven working days. When we remember how few of these suggested alterations survive at the present day, we have a sad picture of disappointed hopes as we contemplate the efforts which were then being made.

Attention was naturally directed to changes in the size and shape of the furnace, so as to permit of the working of larger charges of metal, and to render the work of the puddler less onerous and exhausting. Some of these larger mechanical furnaces met with a measure of success, and the idea of a tilting or oscillating furnace is again receiving attention. My own view is not favourable to the use of large furnaces for puddling. Large masses of iron require suitable machinery for their manipulation, and it is no use to alter the furnace without altering the whole of the rest of the works to suit. Where large masses are to be dealt with, it is so much easier to handle fluid metal than large blooms of iron at a welding heat. Ingots can be made true to size and shape, and can be stored and reheated if required. It is true that these ingots are not wrought iron, but steel. But for the world's needs steel is "just as good," or even better for many purposes than wrought iron. But it is not wrought iron, and has properties which are for many purposes absolutely different. I am inclined to think also that wrought iron made and worked in these large masses would only prove to be "just as good" as that made in smaller balls of less than 1 cwt. in weight by the labour and skill of a good puddler. Even when mild steel scrap has been mixed with wrought iron, worked on a ball furnace, and subsequently rolled into bars, the result is not a satisfactory wrought iron. The tenacity may be higher, and for some purposes it may even be better than puddled iron. But every piece of steel still retains its own characteristics, and can be recognised under the microscope. The bars do not resist oxidation well, and are otherwise unsatisfactory. When Bessemer steel was first introduced, it was expected that Sheffield crucible steel would soon be a thing of the past. More recently crucible steel has been threatened by the electric furnace. It seems to be now established that however pure and excellent electrically refined steel may be, and though it may in some respects be even superior to crucible steel, still it is not quite the same, and Sheffield, rightly or wrongly, adheres to its old method and produces its old quality. In the wrought iron trade I am inclined to think that something of the same nature will continue to hold good. There is a trustworthiness and quality in puddled iron which has been well and skilfully made by the ordinary process, such as cannot be exactly reproduced either in the best steel or with regularity in metal made in any large mechanically-worked furnace. The future of wrought iron is, I believe, more dependent upon quality and uniformity than upon rapidity of output or reduction in price. If for special purposes wrought iron is the best material and costs more to make, then it should command a higher price.

If it be then assumed that, in the majority of cases at all events, small puddling furnaces are to be retained, the question of fuel consumption is settled to this extent that regenerative gas furnaces are out of court. Economy of fuel is to be looked for rather in the direction of the use of cheaper fuel, the complete combustion of its carbon, and the utilisation of the waste heat for steam-raising or other suitable purposes. For mill furnaces regenerative working is advantageously employed, and in such cases excess of steam from the waste heat of the forge finds a profitable application in the mill. There are usually so many possible applications for waste steam that no heat should be wasted which can be profitably employed. In the West of Scotland, I believe, much progress has been made in the utilisation of small fuel in connection with the production of malleable iron, and in this direction the Glasgow district has given a distinct lead to other localities.

My address this evening has been in the nature of a plea for the fuller recognition of the place which wrought or malleable iron holds in the world to-day, and the part which it appears destined to play in the future. I have also endeavoured to show the importance of some scientific knowledge in connection with puddling. We want such knowledge, in its simplest and most practical form, to be within the reach of those by whom it has to be applied.

CORROSION OF SPIKES IN TIES TREATED WITH ZINC-CHLORIDE.

A report prepared by Mr. Wm. Camp, dealing with the corrosion of spikes in ties treated with zinc-chloride, is given in the "Bulletin" of the American Roadmasters' and Maintenance of Way Association.

During the past 12 or 15 years, the report states, the use of the zinc-chloride process for treating ties has extended to numerous railways, and with this largely extended use of the process there have been instances where serious corrosion of spikes (and tie-plates also) has occurred. Such damage, however, is by no means general. On some roads, where such ties have been in use in large numbers for many years, there is no evidence of corrosion of track fastenings (either in hard-wood or soft-wood ties). On other roads, the corrosion appears in some localities, while in others it is absent. The cause of the corrosion is not well understood. In the earlier days it was laid to the presence of free acid in the treating solution, and this may be responsible for cases of recent occurrence. The treatment of ties is now done more largely by contracts, and there may be more hasty methods of handling the ties, with possibly less attention to the purity of the solution. The remedy is adequate inspection at the treating plants by representatives of the railways.

In the Wellhouse process, a weak solution of glue and tannin or tannic acid is either mixed with the chloride or is applied later as a separate solution, in order to plug up

the cells and prevent the entrance of moisture to leach out the zinc-chloride salt, which is easily soluble. It has been claimed that no corrosion of spikes has been noticeable where glue and tannin have been used. On some roads it has been noticed that while steel spikes have been appreciably corroded in zinc-treated ties, iron spikes have shown no evidence of corrosion.

The most widely prevailing opinion as to the cause of corrosion has reference to the seasoning of the ties after treatment. It is thought that if zinc-treated ties are immediately put into the track the spikes will corrode, but that if the ties are permitted to dry out, so that all the salt has solidified, there will be no appreciable corrosion. It is an interesting fact that in all cases of corrosion the action on the spike is most intense at the face of the tie. Others claim that the supposed greater activity of the corrosion in freshly treated ties is due to galvanic action, and that when once the solution in the tie becomes evaporated, the dry salt will not act upon the spike or other fastening. Contrary to this view is the fact that spikes in tracks at the doors of tie-treating cylinders, constantly exposed to the dripping of zinc-chloride for periods, as long as ten years, show no evidence of corrosion, while spikes in untreated ties in main track (in the same neighbourhood) in service the same length of time, have become badly corroded. However this may be, it is in line with good practice to give treated ties time to season before putting them into the track, as the zinc-chloride, once solidified, is less liable to be leached out of the tie by the dampness of the ballast.

On electric railways the corrosion of spikes is more frequently met with than on steam railways, and it is thought that it is more rapid in zinc-treated ties. It seems to be agreed that the corrosive action is caused by electrolysis from the currents which escape to the ground from the return circuit of the track. In the case of ties treated with a metallic salt the path to the ground would naturally be easier than through untreated ties. There is the question of a similar action on the spikes from the track circuits of electric block signals. Enquiry, however, fails to show that any case of spike corrosion can be traced to the signal circuits. It might be worth while to investigate whether the corrosion of spikes in steam railway tracks might not in some cases be caused by stray ground currents originating in an intersecting or parallel track of an electric railway.

On a railway system where corrosion of steel spikes in zinc-treated ties had occurred, experiments were undertaken to determine the relative corrosive effect on spikes driven in untreated ties, in ties treated with zinc-chloride and in ties treated with water. After seven years of service the spikes were pulled out and it was found that corrosion had taken place with all the spikes under the three test conditions, and that the differences were so slight that conclusions in favour of any of the three seemed unwarrantable. On some roads where corrosion has occurred it has been found difficult to determine whether or not the corrosion in treated ties was more than in the untreated ones. This makes it certain that some other agency than zinc-chloride was responsible for at least some of the corrosion. On other roads, inspection has shown that corrosion of spikes on zinc-treated ties was caused by the brine drippings from refrigerator cars.

Overheating and Burning of Steel.—A lecture on this subject was delivered by Dr. J. E. Stead, F.R.S., at a recent meeting of the North-east Coast Institution of Engineers and Shipbuilders. Dr. Stead lectured to the North-east Coast Society some time ago on the practical use of the iron carbon equilibrium diagram, but was unable to complete his remarks, and, before proceeding to deal with the subject of his recent lecture, dwelt for a few minutes on the equilibrium diagram. Afterwards he showed that overheating of structural and soft steels does no permanent harm to the material, and that burnt steel, under certain conditions, may be made equal, in good properties, to the same steel before burning.

ILLUMINATION OF ENGINEERING WORKSHOPS BY GAS, ELECTRICITY, AND OIL.*

(Concluded from page 170.)

Oil.

By J. E. Evered.

Before referring to the special uses of oil in lighting factories, a few introductory words may be said on industrial lighting in general. It is now almost a truism to say that a factory which is insufficiently lighted is also one that can hardly hope to turn out the best class of work. Improved illumination has become a necessity in view of the advance in accuracy in modern engineering. When it is recalled that the annual cost of lighting of many businesses is almost always a very small percentage—sometimes actually less than 1 per cent.—of the bill for wages, one can easily understand how the cost of improved illumination up-to-date may be more than compensated for by the improvement in output and quality of the work.

The choice of an illuminant for factory lighting depends very largely on the local conditions and on many factors which are not included in the conventional comparisons of cost. Calculations of expense in the form of cost per 1,000 c.p. hours, are no doubt useful as a rough guide to the performance of a lamp; but there are almost always other circumstances to be taken into account. The real problem resolves itself mainly into the position of a certain illumination on the working tables or benches, &c., in a room of specified size, and devoted to stated purposes. Such questions as the range of candle-power available, the amount of trouble needed to keep them clean and in working order, the convenience with which they can be applied to diffuse and distribute the light in all directions, and the readiness with which provision can be made to avoid glare and dazzling effect—all these are matters to be considered.

Every factory really requires to be treated as a separate problem, and to receive the kind of illumination specially suited to the work carried out. For example, in shops where large objects are carried out, foundries, machine shops, goods yards, &c., the provision of a general illumination by powerful lamps placed high up will be considered best. A great deal of discussion has taken place as to the amount of light necessary in such cases, and the impression seems to be that while half to one foot-candle may be enough to enable people to see their way about, two to four foot-candles is nearly always desirable where any close work has to be done. Assuming the lamps are to be hung a sufficient height to preclude any possibility of glare, we have next to consider whether they will distribute the light evenly, and what is the correct spacing for them. There are also other cases, such as work at the lathe and bench, when very fine detail has to be examined, where a strong local illumination from well-shaded lamps may be necessary. This is obviously a factor which may have an important bearing on the choice of an illuminant, since it is not always easy to provide local shaded lamps of the requisite candle-power. One other illustration of such special circumstances may be mentioned. When very complicated machinery is to be examined, the perfection with which the light is diffused in all directions is most important. The illumination should be schemed out so that the light can get into all corners and crannies.

I have entered into these general questions in order to show how many are the circumstances to be borne in mind in choosing an illuminant, and it may be added that there is equal opportunity for skill in the way in which the lamps are arranged when selected. Let me now turn to the main subject of my paper, namely, oil lighting for factories. The light given by wick oil lamps depends materially on the level of oil in the reservoir, and a diminution in light of 20 to 30 per cent. or more can readily be produced in this way. It is therefore advisable to keep the well of the lamp constantly filled up. Judged in this way, the oil lamp, costing 8d. to 9d. per thousand candle-power hours, comes quite low down in the list, while the candle is almost the most expensive method of lighting in common use. In large works the

* Abstract of papers read before the Manchester Association of Engineers, January 25th, 1913.

amount of attention required by the wick of the oil lamp precludes its being used to any great extent. It may also be pointed out that the fact of the oil reservoir being underneath the light is disadvantageous, since it is apt to cast a shadow immediately under the lamp. Lamps burning oil through a wick in the ordinary way can scarcely compete with ordinary illuminants on the ground of efficiency, although they may be serviceable in cases where only a small light is required, and in remote districts. But the efficiency of oil lighting has been enormously increased during the last few years by the invention of the incandescent mantle and its use in conjunction with a burner using oil vapour. Various systems of this kind have been contrived.

In the petrolite lamps use is made of air sucked through a porous reservoir impregnated with suitable hydro-carbons, the mixture of vapour and air being burned in a suitable Bunsen burner. These lamps are claimed to be very safe in action, but they have been employed mainly for domestic purposes. There are other lamps using paraffin vapour with an incandescent mantle representing another form of illuminant of this type, and there is also the well-known petrol-air gas system, in which a small percentage of petrol vapour is generated and passed through pipes to the burners, where it can be turned on and off in the same manner as gas. There are now quite a number of such plants on the market, but the petrol air-system hardly comes within the scope of oil lighting properly understood.

I now come to the system with which I am most familiar, and which is pre-eminently adapted for factory lighting. I refer to the Kitson oil vapour system. The development of this system of lighting was described in a paper before the Royal Society of Arts, by Mr. Arthur Kitson, in 1903. The essential point is that petroleum vapour is generated under pressure and supplied to a Bunsen burner.

The essential elements in the Kitson system are three, namely, the lamp (Fig. 1), the oil reservoir, and the tubing. The oil is kept in a special reservoir of drawn seamless steel, fitted with a glass gauge to show the quantity of the oil in the tank, a pressure gauge, and a check valve for automatically cutting off the supply in the event of any damage being done to the pipes. The reservoir may either be immediately connected to the lamp, so as to make the whole arrangement self-contained, or it may be situated at some distance, the oil being forced along the pipes to the lamp by suitable air pressure.

The reservoir is filled one-third full of petroleum (a special variety of oil is supplied)* and air is forced into it by means of a small hand pump until the gauge shows that a pressure of 55lbs. to 75lbs. per square inch has been obtained. Immediately below the pressure gauge there is a valve; when this is opened oil is allowed to flow into the tube attached to it, by which it is conveyed to the vaporising tube in the lamp. This vaporising chamber is kept at a high temperature in a manner to be described shortly, and the vapour is ejected into the mixing cup and thence into the mixing tube. In passing in, it carries with it a sufficient amount of air to support combustion; thus the oil vapour and air become thoroughly mixed to form a highly combustible gas, which is led into the burners and brings them to a vivid incandescence.

Once the lamp has been started the vaporisation continues automatically, the heat of the lamp being sufficient to keep the parts into which the oil is injected at the necessary temperature. It is, however, necessary to start the lamp by some pre-heating device, and there are three chief methods in use:—

(1) *Spirit Ignition.*—This is the simplest and most economical method when only a few lamps are installed. A small can is provided which contains the exact quantity of spirit required, and this is poured into a cup fitted on the reflector, whence it passes down a tube into the burner and is ignited by a match. The burning spirit heats up the vapour tube, and in about one minute this becomes sufficiently hot. The oil may then be turned on at the supply valve and becomes ignited, and the lamp continues to work automatically.

(2) *Gas Ignition.*—When gas is available in a building, a Bunsen burner and pilot jet may be fitted under the vapour tube and connected with the gas mains. By pulling the chain gas is turned on and ignited from the pilot, and in about one minute heats up the vapour tube sufficiently. As soon as the mantle becomes incandescent, the burner is turned off and the gas consumed is therefore very little.

(3) *Electrical Ignition.*—This system is used in conjunction with spirit, and enables the lamp to be conveniently started from a distance. A switchboard is fixed to the wall in a suitable place, and on this is fitted an injector by which spirit is forced into the burner. An electric spark between two electrodes ignites the spirit. This spark is readily produced from a battery of dry cells. The period of heating up in this case takes about $1\frac{1}{2}$ minutes.

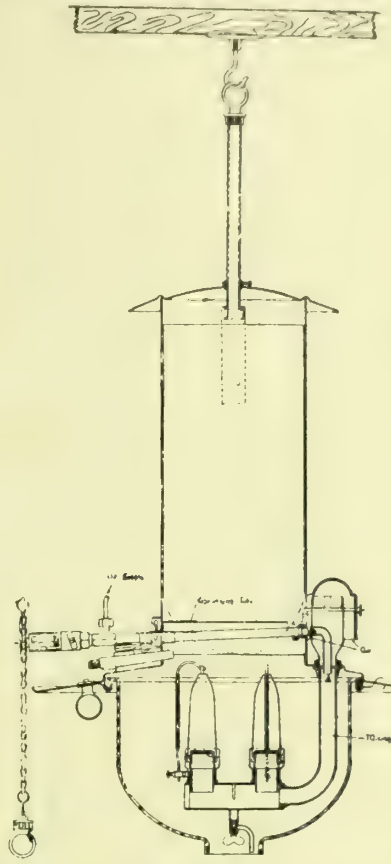


FIG. 1.—SECTION OF KITSON LAMP FITTED WITH LEVER-NEEDLING ARRANGEMENT AND BUNSEN BURNER, FOR GAS IGNITION.

The largest lamps give approximately 1,000 c.p., and it is considered that 1,000 candle-power hours can be obtained from such lamps at a cost of less than one penny. Tests show that the maximum intensity is received at an angle of 40° to 45°, which renders the lamp very suitable for lighting large areas. Smaller lamps with a candle-power ranging from 150 to 500 are also available.

The advantages of such a system as this are considerable. Quite apart from the cheapness with which the light is produced, the fact that the lamps are self-contained and can be removed in a minute and transferred to another part of the building is frequently a great advantage. When special work has to be done in one part of the works, there need never be any difficulty in securing the required illumination. Incandescent oil lamps are frequently employed by contractors doing repairs in the streets and docks, in the case of buildings in course of construction, &c., where neither gas nor electricity are available.

While self-contained lamps are of the greatest value when lamps require to be shifted, it is often convenient to supply oil from a single central reservoir through pipes when a workshop is lighted by a series of lamps in fixed positions. At the Philadelphia Exhibition in 1899 100 lamps were supplied from one tank in this way. As an illustration of the economy of space, it may be said that a space of 10 sq. ft. was all that was needed to provide light equivalent to 200,000 c.p.

* It may be remarked that it is essential to use the good quality of oil recommended for these lamps; inferior varieties lead to carbonisation and the deposit of soot, which is apt to choke up the burner.

Were a similar light to be produced by gas or electricity a very much larger space for engines, boilers, dynamos, &c., would undoubtedly have been required. By the aid of the pressure supplied to the oil it can be carried quite a considerable distance through pipes; it is, in fact, practicable to run oil pipes into houses in a manner similar to that in which gas and electricity are supplied.

Reference should next be made to one of the latest improvements, namely, the substitution of an inverted mantle for the upright one previously employed, and the improvements in the mechanism of the lamps resulting. The latest self-contained inverted lamp, giving an improved distribution of light, takes only two minutes to charge with oil and air, and can be fixed and started in one minute. With the larger type of lamp (say the 1,200 c.p. type) as much as 14,000 candle-power hours can be obtained from one gallon of oil, and all sizes will normally run from 100 to 150 hours without cleaning. Fig. 2 shows the details of its construction.

In the design of this lamp the main features are the accessibility of working parts, simplicity of construction, elimination of renewal replacements, such as needles, gauzes, burner caps, &c. The case of the lamp is a solidly-designed,

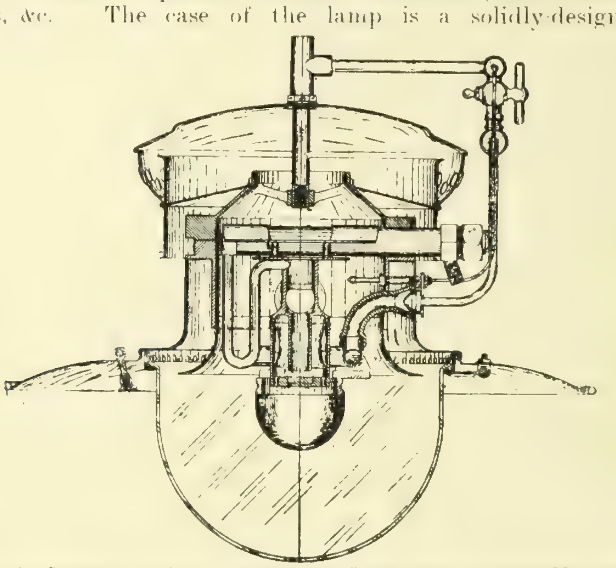


FIG. 2.—SECTION OF "STILL" SHORT-TYPE LAMP, USING INVERTED MANTLES.

accurately-machined, hinged casting, into the bottom of which is fitted the air and venturi tube and burner. These are solid, heavy castings, which will not burn out, being made of a special bronze alloy, capable of withstanding great heat. The vaporiser, which is of novel construction, lies across the air tubes, fitting into a socket on them, and into a recess on the casting. The base casting is closed and held by a screw projecting from the top portion. On to this body casting is fitted a reflector, so constructed as to give an annular space around the casting, which allows for warming the air before intermixing with the vapour issuing from the vaporiser nipple. It will be observed that the reflector can very easily be detached and exchanged for another if it is desired to alter the distribution of light.

The lamp is made in two types, a long type for outdoor, which is self-contained, and a short type for indoor use. In the long type the annular space is taken right up the chimney, to ensure that the air is made warm and to increase the draught, which might be disturbed by gusts of wind or other chilling influences. It is essential that the air should be warm before being admitted to vapour lamps of this type, because cold air chills the nipple, and this causes carbon deposits to form quickly. The vaporiser has a main tube of large bore, which lies horizontally across the air tubes, and from which a tube of smaller bore, bent "U" shape, is taken vertically down as close to the mantle as possible, returning to a central socket on the main vaporiser. Into the main vaporiser is fitted a deposit tube of slightly smaller bore. This forms an annular vaporising chamber, oil being admitted from a connection at the end of the vaporiser outside of the lamp. The deposit tube is kept cool by means of a circulating strip which runs up its centre. The cooler surface of the deposit collects the solid or less volatilisable constituents of the oil, and can be easily withdrawn for cleaning at any time. After the vapour has passed this tube, it is conducted through a specially-designed metal filter, which further removes any solid particles. This filter is designed so that it can be easily taken out and cleaned or renewed. The vapour is superheated in the "U" tube, and passed on to the nipple.

Besides the simplified construction of this lamp, the use of an inverted mantle has proved decidedly beneficial. Mantles of this kind seem particularly suitable for incandescent oil lighting from the standpoint of efficiency, and they are less fragile—an important point in the case of lamps which are carried from place to place, and apt to be subjected to rough treatment.

The Kitson system is remarkably safe, for the oil supply cannot be set alight at ordinary temperature, and only becomes combustible in the vaporising tube of the lamp. A leakage from the pipes would not, therefore, lead to any possible danger. One other advantage of the system may be mentioned, namely, the high penetrating power claimed for the rays issuing from the Kitson lamp.

And now let us turn to the problem of lighting the bays in the machine shop. Let us take first the two large bays, each 250ft. long, 50ft. broad, and 30ft. high. These are devoted to heavy machine tools and the erection of machinery. For such work some authorities consider a general illumination on the working plane of about 2 to 3 foot-candles, but personally I think it is better to err on the right side, and the method of lighting I propose should give quite 3 to 5 foot-candles on a working plane 3ft. above the ground. Taking an average of 4 foot-candles, I estimate that each of these big bays would require about 16,000 c.p., and with high-pressure oil lighting the running cost per 1,000 c.p. hours should not exceed one penny. A rough estimate, therefore, suggests a running cost per hour of 1s. 4d. per bay. The new inverted burner lamps would preferably be employed. They would probably be hung at a height of about 14ft. to 16ft. (well below the probable level of the travelling crane). Such lamps possess a distribution curve approximating to the "extensive" type, and may conveniently be spaced at a distance apart about equal to twice their height.

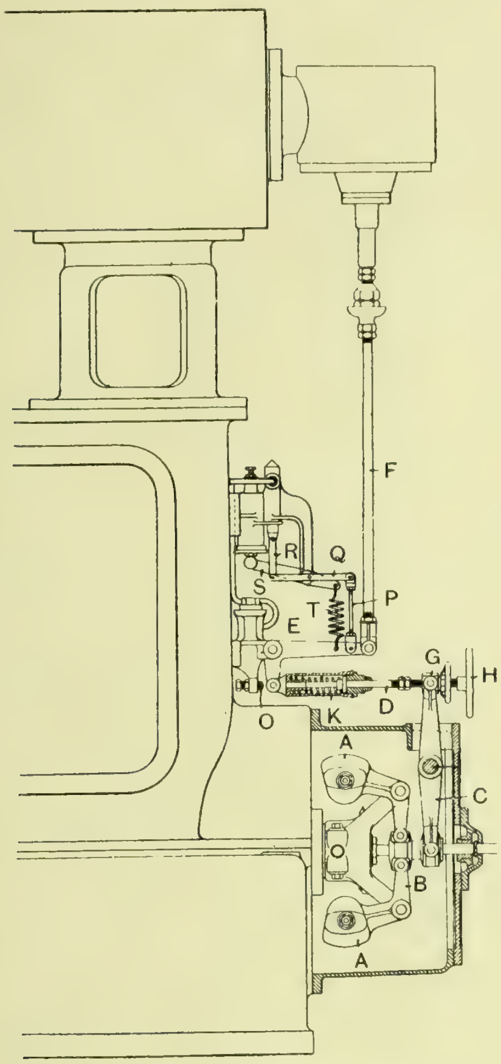
We may therefore propose two sets of eight 1,000 c.p. lamps, hung off brackets from either side of the bay, and projecting about 6-8 ft. from the wall or pillars to which they are attached. The distance between lamp and lamp across the bay will be 34-38ft., and the distance between successive lamps down the line of the kop about 32ft., which complies well with the spacing for uniform illumination. The value of illumination named above should easily be obtained with this arrangement. The lamp at the height specified will be well above the eye level, and will not give rise to glare, and they will comply with the requirement of not interfering with the crane; the motion of the crane, being above the lamp, will not give rise to shadows. The running cost of the 32 lamps required for both bays will be about 2s. 4d. per hour. The initial cost of supplying lamps, piping, and everything necessary will depend upon conditions, but will probably not exceed £192.

The three small bays, each 250ft. long, 30ft. high, and 30ft. wide, will only require a single row of eight lamps down the centre of the room, at about the same height as before. As these bays are devoted to small machinery a good local illumination of three to four foot-candles will certainly be necessary, and this will be provided. The central arrangement is also an advantage in that it will keep the lamps clear from the belts, which will probably be most of them located at the sides of the room. Should the number of belts be very considerable, it might be desirable to use twice the number of 500 c.p. lamps. The running cost of the lamps in each of these small bays should not exceed 8d. per hour, *i.e.*, 2s. per hour for the three bays. The cost of installation for the three bays would probably not exceed £144.

It is hardly necessary to say that the exact details in these schemes might have to be modified somewhat, according to the nature of the surroundings, the exact kind of work done, and the disposition of the machinery. I hope, however, to have said enough to show what incandescent oil lighting can do.

BELLISS & MORCOM'S CENTRIFUGAL GOVERNOR.

The accompanying illustration shows a design of centrifugal governor, the invention of Messrs. Belliss & Morcom, Ld., Ledsam Street Works, Birmingham, and Mr. J. M. Walshe, which is adapted to be so adjusted, whilst the motor is running, as to cause the governor to automatically control the motor to run at any desired speed, within a relatively large range of speed, and remain running at the selected speed with only a small fluctuation therefrom. A are the weights of the governor, which are rotated in the usual manner by the crank shaft of the engine, and the springs of which by their extension are adapted to balance the centrifugal force developed at any selected speed. B is the sleeve which is displaced by the bell-crank levers of the governor weights. C is a rocking lever pivoted as shown,



Belliss & Morcom's Centrifugal Governor.

and connecting the sleeve B with an adjustable link D. This link is, through a spring device, connected to the shorter arm of a bell-crank lever E, the longer arm of which is connected to the rod F of the steam supply valve. The link D is screw-threaded for a portion of its length, and on this screw-threaded portion is mounted a nut G which constitutes the connection between the rocking lever C and the link D. The link D is rotatable by means of a hand-wheel H so that the nut G can be displaced along the link, whereby any portion of the travel of the governor-sleeve B can be selected to control the travel of the valve.

After adjustment has been effected, the nut G can be locked against unintentional displacement by means of a second nut formed as a hand-wheel, and the travel of the nut G along the link in a direction to shorten the latter is limited by a pair of nuts which are mutually locked one against the other. Displacement of the nut G towards the outer hand-wheel end of the link D will render operative a portion of the travel of the governor-sleeve B corresponding to a more outwardly displaced position of the weights A and to a higher rate of revolution, whereas displacement of the nut G towards the bell-crank lever E will render operative a portion of the travel of the governor sleeve B corresponding to a less outwardly displaced position of the weights A and to a lower rate of revolution.

The spring device above mentioned which connects the link D to the short arm of the bell-crank E, consists of a tubular casing K, pivoted to the short arm of the bell-crank E, and containing a spring of sufficient stiffness to transmit the thrust of the link spindle D for displacing the valve when the speed temporarily falls below that to which the governor is set. The spring, however, yields when the valve is fully open and thus permits the governor weights A to seat themselves against stops under the tension of their springs when the engine comes to rest, so relieving the interconnecting mechanism of the stress due to the springs. An adjustable stop O limits the displacement of the short arm of the bell-crank E and relieves the valve when fully open of the thrust of the spring in the tubular casing K.

To enable the arrangement under notice to achieve its purpose with great precision, even when subject to changes in the load on the engine, it may be combined with the auxiliary apparatus, as shown on the accompanying drawing, wherein the longer arm of the bell-crank lever E is connected by a link P, lever Q and link R with the control valve of the auxiliary apparatus and the longer arm of the bell-crank lever E is acted upon by the plunger of the auxiliary apparatus, through a lever S and spring T.

BAYER'S STEAM METER.

The following is an interesting record of a recent test with a Bayer's steam meter, made by Dr. Nicolson and R. M. Ferguson, at the Municipal School of Technology, Manchester. The meter, which is manufactured by Messrs. Schäffer and Budenberg, of Whitworth Street, Manchester, measures the weight of steam passed through it per hour, and, as will be seen from the results in the appended table, it gives results which agree with remarkable closeness to the actually weighed quantities under a wide range of pressure. At 100lbs. the results were in fact coincident, and the maximum error observed when the pressure was reduced to 30lbs. was only 4·2 per cent., while the average error at 70lbs. was little over 1 per cent. The construction of the meter, we may add, was described in our issue for October 25th, 1910 (see p. 546, Vol. XXVI.).

Table showing results of Tests on a Bayer's Steam Meter carried out at the Manchester School of Technology.

Date of Test.	No. of Meter.	Size of Meter.	Steam Pressure. Lbs. per square Inch Gauge.	Steam Indicated by Meter Lbs. per Hour.	Actual Steam through Meter Lbs. per Hour.	Error Lbs. per Hour.	Error per Cent.
		Ins.					
9th May, 1912	102	2½	70	730	721	+ 9	+1·25
9th May, 1912	102	2½	70	1,915	1,905	+ 10	+0·5
10th May, 1912	102	2½	70	1,861	1,836	+ 25	-1·36
13th May, 1912	102	2½	70	655	636	+ 19	+3·0
13th May, 1912	102	2½	30	445	427	+ 18	+4·2
13th May, 1912	102	2½	30	1,436	1,400	+ 36	2·57
13th May, 1912	102	2½	100	2,584	2,580	+ 4	–
9th July, 1912	104	2½	80	779	800	21	2·63
9th July, 1912	104	2½	80	2,280	2,340	60	2·56
11th July, 1912	111	2½	140	1,370	1,390	20	—1·44
11th July, 1912	111	2½	140	2,410	2,460	50	2·03
12th Nov., 1912	112	4	100	4,390	4,440	50	—1·13
14th Nov., 1912	112	4	50	1,962	1,980	18	—0·91
14th Nov., 1912	112	4	46	2,840	2,848	8	0·28
7th Jan., 1913	113	8	77	6,180	6,210	30	0·5
17th Jan., 1913	114	8	82	6,670	6,650	20	+0·3
21st Jan., 1913	115	8	80	6,540	6,620	80	1·21
28th Jan., 1913	116	8	80	5,450	5,340	+110	2·06

The Society of Engineers. An ordinary meeting of this society will be held on Monday, March 3rd, at the Institution of Electrical Engineers, Victoria Embankment, W.C., when Mr. John Kennedy (president, 1912) will present the premiums awarded for papers published in the "Journal" during 1912, after which Mr. Arthur Valon, the president for 1913, will then deliver his presidential address.

A GERMAN DESIGN OF WATER-TUBE BOILER.

THE construction of water-tube boiler illustrated, has been designed and patented by Messrs. Babcock & Wilcox, of Oberhausen, Rheinland, Germany. It is provided with an economiser installation arranged for heating the feed water, whereby the furnace gases are utilised to advantage. Fig. 1 is a longitudinal vertical section, and Fig. 2 is a cross section on the lines X—X and Y—Y, Fig. 1, of the boiler. The main generating element is arranged within the furnace and comprises inclined water-tubes B extending between front and rear headers connected, respectively, by means of downcomer tubes E and return tubes F, with an overhead steam and water-drum G. A steam-receiving drum H is disposed above the drum G and connected thereto. The space between the water-tubes B and the return tubes F may be utilised by locating therein a system of tubes comprising a superheater, as shown in Fig. 1. Located in a chamber on each side of the furnace is a group of substantially vertical

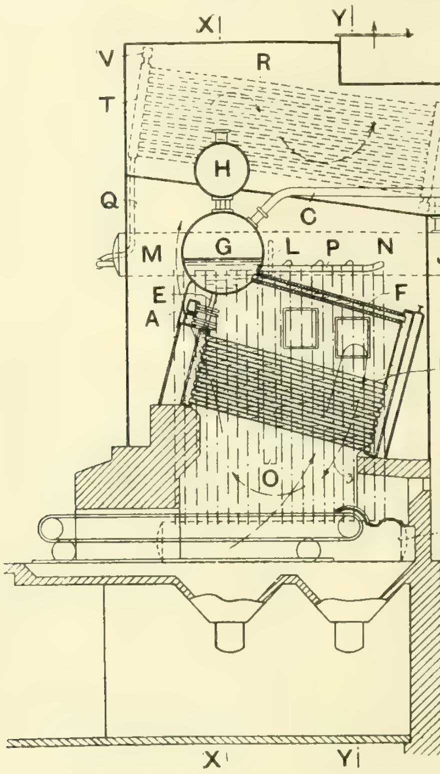


FIG. 1.

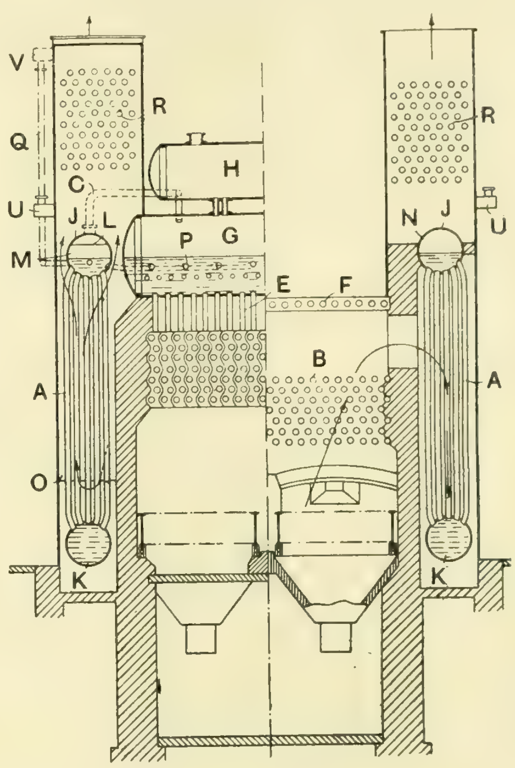


FIG. 2.

A GERMAN DESIGN OF WATER-TUBE BOILER.

tubes A, which in Fig. 1 are indicated by dotted lines, connected to upper and lower drums J and K, each drum J being sub-divided internally by a transverse diaphragm L extending upwardly from the lower part of the drum J and arranged so as to afford communication between the steam spaces of the front and rear drum portions M, N separated by the diaphragm L, a pipe C connecting the drum J with the steam space of the drum G. The tubes A connected to the front portion M of each drum J are separated from the corresponding tubes connected to the rear portion N thereof by means of a depending partition O, the rear portion N being connected to the drum G by means of tubes P and the front portion M being connected by means of a pipe Q to a water heater or economiser disposed horizontally above the corresponding upper drum J, each economiser including inclined water-tubes R connected to end headers S and T, the inlet to, and the outlet from, the economiser being shown at U and V respectively. The passage of the furnace gases is indicated by the arrows. The installation is arranged to operate as follows:—

The feed water enters each heater or economiser at U and passes therefrom by way of the piping Q into the corresponding top drum J, at the front portion M thereof thence through the tubes A and into the lower drum K, the feed water then rising through the tubes A connected to the rear portion N of the upper drum J and passing by way of the tubes P into the overhead drum G of the main generating element wherein the water is circulated.

DEVELOPMENTS IN THE PREPARATION OF IRON ORES.*

BY J. W. H. HAMILTON.

THE rapid growth of the mining industry during the latter part of the 19th century was accompanied by a great development of metallurgical processes for the utilisation of ores that, on account of their low grade or refractory nature, had been considered of little or no value. Although a great many students of ore conditions have long recognised the fact that the beneficiation of low grade iron ores was becoming one of our most important problems, the general opinion has been that iron ores of sufficiently high grade to use in their crude state in the blastfurnace were so abundant that there would be no necessity of utilising the lean ones. Until recently, the opinion has also been prevalent that, with few exceptions, the low grade ores could not be dressed and transformed into a product suitable for the blastfurnace at a cost low enough to make it possible to sell this product at a fair profit in competition with natural ores. The work of geological institutions and the statistics on the consumption of iron ores have rapidly changed the general opinion and have attracted attention to the low-grade ores.

In 1870 the iron ore produced in the United States was 3,831,891 tons. Since that time the production has been doubled about every 10 years, and in 1910 it reached the impressive figure of 56,889,784 tons. If the same rate of increase is kept up during the present decade, we shall be mining over 100,000,000 tons in 1920. In other words, we shall then be mining at the rate of over 1,000,000,000 tons in 10 years. In Europe the increase in production during the same period was not so rapid as in the United States, but iron mining has there also attained such proportions that a marked depletion has taken place in a great many of the iron mines. It was less than two decades ago that the old Bilbao mines in Spain, which for half a century have been among the chief shippers to English, French, and German furnaces, were considered almost inexhaustible. To-day these mines show evidence of rapid decline. It is, therefore, gratifying to note that great interest is being manifested in the conservation of natural resources. An expression of this interest was the request that was sent out to all civilised nations to take stock of their iron ore resources and submit their figures to the eleventh International Geological Congress, held in Stockholm in 1910. The records of this congress show that the known and recorded high grade iron ore deposits containing 60 per cent. or more metallic iron are very limited, the actual reserves being estimated at 1,300,000,000 tons and the potential at 687,000,000 tons. Out of these 1,095,000,000 tons actual and 123,000,000 tons potential ores are recorded for the Swedish mines. Very large ore reserves averaging from 50 to 60 per cent. metallic iron exist in various parts of the world, but the great mass of iron ores contain on an average much below 50 per cent. iron.

Most mines are now equipped with crushers, which break the ore to about 4in. before it is shipped to the furnaces. In Europe the buyers' specifications generally call for ore crushed to 6in. or 8in. Since the steam shovel was introduced for loading ore mined in open cuts, the crushers have been gradually increased in size until they now are built so

* Paper presented at the Pittsburg meeting of the American Iron and Steel Institute.

large that they can break rock of any size that can be handled by the shovel. The crushers used in connection with iron ore mining, and particularly in connection with steam shovel mining, are of the jaw and gyratory type and the Edison giant rolls.

The jaw crusher can be built with a receiving opening that can take a larger rock than a gyratory of the same weight. A gyratory crusher can be built to give a larger output of a certain size than a jaw crusher of the same weight. In the case of the largest crushers the capacity does not make much difference, because it is generally so great that it is not practical to get the ore to the crusher fast enough to load it to its full capacity. It is claimed that the gyratory consumes less power per ton of crushed ore than the jaw crusher. This may be true of slabby material, which is easily broken in the gyratory. A slab will rest both its ends on the concaves and the cone will hit it in the middle and break it with the exertion of very little power. A gyratory is, therefore, often termed a breaker instead of a crusher. There are few test records of any value for the comparison of the actual power consumption of the two types. The largest jaw crusher that ever has been built for iron ores was recently supplied to the Kiruna mines in Sweden, where it will be employed for crushing ore for export. The jaw opening of this crusher is 60in. by 84in. and the weight of the machine is about 400,000lbs.

The Edison giant rolls break the ore by impact and not by crushing as do the ordinary crushing rolls. The surface of the Edison rolls has a number of projections known as sluggers, which, on account of the very high speed of the rolls and their great momentum, give terrific blows to the ore pieces dumped on top of them and smash them to pieces. They are particularly effective on comparatively soft ore of the Cornwall type. This ore goes largely into fines during the mining, and when these fines get wet they become sticky and are likely to choke ordinary crushers. On account of their high speed, the Edison rolls throw off any ore that has a tendency to adhere to the roll shells. The large ore crushers have been found to reduce the cost of mining considerably. Block-holing and sand-blasting have been reduced to a minimum. It is much cheaper to break rock by mechanical power than by dynamite.

Although the washing of soft hematites and brown ores is the ancient method of concentration, the greatest progress has been made in the treatment of magnetites, which on account of their magnetic properties are peculiarly well suited for concentration. The magnetites are concentrated either wet or dry. The advantage of one system over the other depends largely on the nature of the ore. As a general rule it can be said that the coarse crystalline ores can be treated to the best advantage by the dry method, whereas with the fine-grained ores better results are obtained by the wet system.

The coarse-grained ores are generally easy to concentrate, and the concentration can be done at a very low cost. The most expensive part of the operation is the crushing; and the coarser the grain, the less the cost. In many ores it is necessary only to eliminate pure rock which happens to get mixed with the ore in mining. In such cases a cobbing of the ore after it has been crushed to about 2in. is all that is necessary. Coarse-grained magnetites are abundant in several States. The large ore deposits of northern Sweden and those of the Grangesberg mines are principally of this type. The most interesting separating plants working on coarse crystalline magnetites are those of Witherbee, Sherman, & Co., Mineville, N. Y. Experiments with magnetic separation were begun here as early as 1852, but it was not until the 80's that the magnetic separation became a commercial possibility. Since that time its development has been rapid. New mills have been built from time to time, and to-day the company has the largest magnetic separating equipment in the world. The aggregate capacity of the four mills, when operating only one shift, exceeds 1,000,000 tons per year. As the milling system here represents the most up-to-date practice in dry magnetic concentration, we will discuss the various problems principally as they occur in connection with this plant.

The cobbing of the coarse material was formerly done by hand, but mechanical cobbing is now becoming more common. At these mines, magnetic-cobbing has completely replaced hand-cobbing, with the results that the cost of operation has been very much reduced, four men now doing the work that formerly took 14; that the cobbed product is absolutely uniform, and that there is no unnecessary loss of iron in the tailing. Within certain limits, the iron content in the cobbed ore can be varied by regulating the magnetic field.

The ore is crushed to 4in. as it comes out of the shaft and is then delivered by belt conveyer to a revolving screen with 2in. perforations. The over-size is re-crushed and returned to the screen and the through-size goes over the cobber. If it is desirable to take out low grade ore as well as high grade, the magnets are given their maximum current and the tailing is immediately discarded. If only a high grade ore is desired, the cobber is given a weak field so that it picks out only the rich ore and the tailing is passed to another cobber with a strong field. The ore recovered on this machine is sent to the concentrator for crushing and separation, and the tailing is discarded.

After the ore has been crushed by jaw crushers and gyratories to about 1½in., the fine crushing is generally done by rolls. For sizes ranging from about 2in. to ¼in. the smooth rolls have been found to be the most efficient crushers. The size of the rolls should be made to suit the size of the material. For effective roll crushing, the material should be carefully sized. Crushing rolls of as large as 72in. diam. and 30in. face are used now on low grade copper ores. These rolls have a very large capacity and can crush ore from 4in. down. The size mostly used for iron ores are 42in. diam. and about 16in. face. Rigid rolls have been tried, but generally with disastrous results. It is, however, good practice to make the springs so stiff that they will give very little unless a piece of iron or steel happens to get in between the rolls. Corrugated rolls have a very good *nip* and can crush coarser ore than the smooth rolls of the same diameter, but the corrugations wear off and then the nipping power diminishes so that the rolls can no longer do the same work. Also, because corrugated rolls cannot be trued without removing the corrugations, they are not much in use.

The No. 4 mill at Mineville, which has recently been placed in operation, is the latest step in the evolution of dry magnetic separating plants. Its most noteworthy features are the flexibility in the milling operations, gained by making the coarse crushing entirely independent of the separation and fine crushing; the close sizing of the material before it is separated; the roll crushing of all fine sizes and the arrangement of the rolls so that any one of the eight sets of rolls can be cut out for repairs without interfering with the operation of the mill. Only the fines are dried, as it has not been found necessary to dry the coarse ore. A vertical stack drier is used for the purpose. Between the crushing and the separating departments is a 1,000-ton storage bin, which acts as a reserve bin, and is, therefore, by-passed in case the crushing and separating departments are in operation simultaneously. The coarse sizes are screened on revolving screens and the fine sizes on vibrating screens. The coarse ore is cobbed on drum type and pulley type cobbers. Two machines are always used in series for a three-product separation. The concentrate from the first machine goes directly to the concentrate bins, the middling, which is the head product of the second machine, goes to the rolls for crushing and re-separation, and the tailing from the second machine goes to the dump. For the medium and finest size ores the drum type separator is used. As it is not always necessary to make a three-product separation of the finest sizes, these separators are arranged so that they can be operated either in series for a three-product separation, or in parallel for a two-product separation.

The capacity of the mill is 100 tons per hour or 1,000 tons per day of 10 hours. As it requires only 14 men to operate the whole plant the labour cost per ton of ore milled is very low. The iron content of the concentrate ranges from 64 to 65 per cent. and the phosphorus is about 0·03 per cent. The mill produces an excellent Bessemer ore which, in common with other products of magnetic separation, has the advan-

tage of great uniformity, no matter how much the raw material varies.

When a fine-grained, low grade ore is crushed to a powder a large portion of it goes into dust. It is difficult to make a clean concentrate from such material on dry magnetic separators, and the handling of the dust becomes a serious problem in the mill. For this reason the wet crushing and separation has been found better adapted for ores of that nature. It has been stated previously that the fine crushing is the costliest part of the separating process, and this is particularly true of the fine-grained ores. The comminution, therefore, should not be carried any further than is necessary to liberate the ore crystals from the adhering gangue. While some fine-grained ores can be separated satisfactorily after a crushing to 20 mesh, others must be crushed to 100 mesh or finer. Through a series of separation and screening tests the proper crushing size can be determined, but a more thorough knowledge is obtained by making a microscopic study of a thin section of the ore.

The coarse crushing methods are the same as in the dry mills, but the fine crushing of iron ores to about 20 mesh is almost invariably done in the ball mill. If the comminution must be carried further, the pebble mill is used. The ball mill is generally fed with ore crushed to 2in. or 1½in.

The largest and most interesting wet mill working on low grade, fine-grained magnetite is the one at Sydvaranger in Norway, about 220 miles north of the Arctic Circle. The ore is mined in open quarry and is loaded by steam shovel. The crude ore averages about 36 per cent. iron and it takes about two tons of crude ore to make one ton of concentrate. In order to make a good separation it is necessary, on account of the fine grain of the ore, to crush it to about 100 mesh. The first crushing is done in two No. 18 gyratories, which have a 36in. opening between cone and concaves. These are followed by jaw crushers, reducing the ore to 2in., which size is fed to the ball mills. The concentrate is dewatered in large concrete settling tanks and is taken from these tanks by overhead cranes and grab buckets to the briquetting presses. The yearly capacity of the plant is at present 500,000 tons of concentrate, one-half of which is briquetted. The rest is dried and shipped in the form of concentrate.

At Moose Mountain, Ont., another concentration plant has been built for treating an ore similar to the one at Sydvaranger. The capacity of the first installation is 350 tons of concentrate per day. Several new features have been introduced. The ore after having gone through the preliminary crushing to about 3in. will be pulverised in impact crushers specially designed by the mining company. These reduce the ore to sufficient fineness for separation. The concentrate from these machines is re-ground in conical mills and is then re-treated on the same kind of separators. A new briquetting machine, which will eliminate the manual labour of transferring the briquettes from the press to the car, is also being developed by the company. The briquetting kilns are gas-fired, and are of the Grondal type. The plant has the advantage over the Sydvaranger plant of cheap water power. The briquettes will contain about 64 to 65 per cent. iron, 0·02 per cent. phosphorus, and 0·014 per cent. sulphur.

(*To be continued.*)

New London and North-western Engines.—A new type of 4-cylinder simple express engine is being tried on the London and North-western Railway. It is of the 4—6—0 type, with coupled wheels 6ft. 9in. diam. The cylinders are 16in. diam. and the stroke 26in. Walschaert valve gear fitted in the outside position has been adopted. The boiler is 14ft. 6in. long and 5ft. 2in. diam., with a Belpaire firebox and large extended smokebox projecting beyond its stays. A sloping grate, superheater, and mechanical lubrication apparatus are fitted. The steam pressure is 200lbs. per square inch. The engine is to be named after the chairman of the company, Sir Gilbert H. Claughton, and nine others that are on order will be called after other directors. These engines will be the largest and heaviest on the London and North-western Railway.

INDUSTRIAL AND TRADE NOTES.

Fusion of Railway Unions.—The three principal unions representative of workers in the railway world—the Amalgamated Society of Railway Servants, the General Railway Workers' Union, and the United Signalmen and Pointsmen Society—have decided to amalgamate under the title of the National Union of Railwaymen. The total membership of the three unions is about 180,000.

The Propelling Machinery of the Battle-ship "Malaya."—The Wallsend Slipway and Engineering Company have received the order for the propelling machinery of the battle-ship "Malaya," which is to be built at Messrs. Armstrong, Whitworth's new shipyard at Walker. The engines will, it is understood, be similar to those fitted in the "Queen Elizabeth," of about 50,000 h.p. The vessel will steam 25 knots an hour.

Cheaper Gas for Sheffield.—Notwithstanding that the Sheffield United Gas Light Company hold the record for supplying the cheapest gas in this country, the directors have decided to make a further reduction. The reduction will, however, only apply to those consumers using over half a million cubic feet per year and to users of gas engines who are to pay one penny less per 1,000. These reductions will make the charges, after the end of this quarter, 1s. 3d., 1s., and 10d. per 1,000 cub. ft. respectively.

Shipyard Agreement Ratified.—The National Shipyard Agreement, as recently amended at the grand conference of the Shipbuilding Employers' Federation and Allied Shipyard Trades Union, has been approved by the majority of the Union members. Representatives of each side will meet in Edinburgh later for the purpose of signing the new agreement, which will remain in operation for three years. The previous agreement was signed in March, 1911. The Boilermakers' Society is not in the new agreement.

Model Engineering Institute.—The Clyde Model Engineering and Electrical Institute, at 12, Craighton Road, Govan, was opened on Saturday last by Mr. Fred J. Stephen, of Messrs. Alex. Stephen & Sons, shipbuilders and engineers, Linthouse. The Institute has been established for the purpose of enabling apprentice engineers and other young mechanics to study their trades and to develop their ideas by experimenting with models. A workshop, equipped with machinery, has been provided in connection with the institute.

New Sheet Mills at Ebbw Vale.—The new sheet mills constructed by the Ebbw Vale Steel, Iron, and Coal Company have just been started. The company's works had to close for a period of six months in 1911 for want of orders. It then occurred to the management that a lack of orders for bars could be met by constructing sheet mills to manufacture the finished article from their own steel products. The new sheet mills are built on the most approved style and driven by electrical power. Ample provision has been made for extension should the new undertaking warrant it. The mills will give employment to some hundreds of men.

Speed Record by a British Motor-car.—On Saturday afternoon last, at Brooklands, the world's hour record for motoring was broken by an Invincible Talbot motor, with 25 h.p. engine, the total distance covered during the hour being 103 miles 1,470 yards. On the way the world's 50-mile record was also broken, the vehicle covering the distance in 29 minutes 2¼ seconds, or at an average speed of 103·30 miles per hour. The motor used was of only 25 h.p. engine, and was of the company's standard touring size. No machine had previously covered 100 miles in the hour, the motors which have for years been attempting the feat being built with engines three or four times as large as that of the Invincible Talbot. The engine is of 101·5 mm. bore, with 140 mm. stroke.

Canal Development.—At a meeting of the Worcester Chamber of Commerce held on the 12th inst., the Council considered a suggestion to memorialise the Prime Minister on the subject of the formation of a Waterways Board. The memorial set forth that the time was now ripe for restoring to traders the use of the waterways. The railway companies admitted that they could not deal with the mass of freight now offered them. It was not yet proved that the waterways needed enlargement. In their present condition they were capable of carrying more traffic than they were now bearing. Members urged that the question of the enlargement need not now be seriously pressed. What was necessary was the formation of a Waterways Board. It was decided to forward the memorial.

Motor-omnibuses in London.—According to the report of the London Traffic Branch of the Board of Trade for 1912, the total number of licensed motor-omnibuses in London in July, 1912, was 2,085, compared with 1,550 in July, 1911, showing an increase of 535, or 34 per cent. Of these, 1,909 omnibuses were petrol

driven, 131 steam driven, and 45 worked on the petrol electric system. The number of passengers carried by omnibuses in London during the year ended September, 1911, was 400,628,487, an increase of 23,420,932 over the previous year. In 1911, 107 persons were killed and 1,947 were injured by motor omnibuses in Greater London. The number of tramcars licensed in the Metropolitan area was 2,755, of which 2,665 were electric, showing an increase of 254 electric and a reduction of 30 in horse drawn cars compared with 1910.

A Large Tyre Rolling Mill.—The Brightside Foundry and Engineering Company, Ltd., of Sheffield, have just completed, for a large American steel works, a very massive tyre rolling mill, which is possibly the most powerful machine of its kind ever built, and, in addition to rolling tyres, will be called upon to deal with very hard steel hoops up to 10in. wide and from 2ft. to 10ft. diam. The mill is on the lines of the "Collier" type, with radial arms for the side rolls, operated through worm and quadrant gear, and the pressure for expansion of the material in rolling is applied by means of a powerful hydraulic cylinder. The main vertical shaft has a supporting bearing on both sides of rolls, and the principal features that have been kept in view in designing the mill are the renewal of all wearing parts, and the adjustment of alignment of shafts as wear takes place.

New Armour Plate.—Mr. William H. Worrall, a Sheffield engineer, claims to have invented an armour plate that effects a net weight saving of 15 per cent. Further, he claims for his invention, which is at present being developed by a private firm, that the resistance of the plate is greatly strengthened. The invention consists of a modification of the whole process of making armour plate, commencing with the ingot, which goes through modifications in the rolling mills and then requires different heat treatment from that provided in the existing furnaces. The ordinary armour plate has a hardened back and front and a soft core. Mr. Worrall's plate consists of a number of small plates hardened and bonded together so that the core of the plate contains layers of steel as hard as the surface. Experiments conducted on somewhat similar lines have not hitherto been attended with success.

Employment in the Engineering Trades.—The Board of Trade Labour Gazette states that employment, on the whole, continued good in January, and was better than a year ago. Employment improved in the coal mining, pig-iron, iron and steel, engineering, and shipbuilding trades, but there was some falling off in the tinplate trade. The changes in rates of wages taking effect in January affected over half-a-million workpeople, whose wages were increased by nearly £27,000 per week. Statistics show that out of 884,444 trade union members, 19,494, or 2·2 per cent., were unemployed at the end of January, compared with 2·3 per cent. at the end of December, and 2·7 per cent. at the end of January, 1912. Returns from firms employing 419,398 work people in the week ended January 25th, 1913, showed a decrease of 0·2 per cent. in the number employed and of 2·5 per cent. in the amount of wages paid, compared with a month ago. Compared with a year ago, there was an increase of 1·6 per cent. in the number employed, and of 6 per cent. in the amount of wages paid. The number of trade disputes beginning in January was 67, and the number of workpeople involved in all disputes in progress during the month was 52,066, as compared with 30,685 in December, 1912, and 190,374 in January, 1912.

Conveyer Patent Declared Invalid.—Mr. Justice Warrington, in the Chancery Division, on the 12th inst., decided an action by Bertram Norton, of Trindle Road, Dudley, claiming an injunction to restrain W. H. Barker & Son, of Etna Works, Fenton, Staffordshire, from infringing letters patent granted to J. F. Zimmer, and now owned by the plaintiff, for an invention relating to plant for screening and conveying coal and other minerals. The principle of the invention was to obtain a horizontal and upward movement in the particular conveyer. The plaintiff complained of infringement at the defendants' collieries at Gresley. Defendants denied the alleged infringement, and said the invention had been anticipated. It was stated, in support of the plaintiff's case, that the specifications prior to the Zimmer patent did not deal with the point of his invention, and therefore they could not have anticipated it. Neither had there been any disclosure of the patent. The upward and horizontal movement was peculiar to the Zimmer patent, and his invention was applicable to a long length as distinct from the earlier patents, which could be applied to short lengths of conveyers only. The Zimmer invention had been largely used, and was very well known. His Lordship disposed of the action without calling upon the defendants' counsel. He held that the patent was invalid. He failed to see sufficient invention to support the patent in merely dividing the conveyer, which was primarily for some other purpose, into sections, for the purpose of claiming exactly the same object which the plaintiff had obtained before in screening apparatus. He therefore dismissed the action, with costs.

Nationalisation of Railways.—Mr. J. Calder, assistant general manager of the North British Company, in a recent lecture on "Railway Nationalisation," said that on the passing of the Act of 1844 (which contained an option to the State to purchase the railways) the total authorised mileage of railways within the United Kingdom was 2,320. At December, 1911, the total mileage of lines opened for traffic was 23,417, an increase of 21,097. The movement in favour of nationalisation of railways in this country had been one of comparatively slow growth, but there were many indications that it was being pressed forward to a greater extent than heretofore. One of the causes of that was the labour troubles in railway and other spheres. But in other countries where the railways were owned by the State strikes had occurred, as, for instance, in Hungary in 1904, and more recently in France. That the railways of the United Kingdom were largely over capitalised, and that gross waste took place in connection with their construction, no one would attempt to deny. That the average cost of railways in Great Britain was much in excess of that in other countries was a matter of general admission. That waste was mainly to be found in Parliamentary charges, law, engineering, and incidental expenses, and sums paid in respect of land and compensation. But it must be borne in mind that every penny of capital which had been raised by the railway companies had been authorised by Parliament. The ownership of railways by the State had been undertaken in different countries for varying reasons—economic, political, or military—and he believed it would be a matter of considerable difficulty to find that in any case the policy adopted was as a result of the alleged superiority of State over private operation. The demand for nationalisation on the part of the public in this country arose from a variety of causes, but he believed there existed the firm conviction that, following the transfer of the railways to the State, the savings to be effected would result in an immediate and substantial reduction in rates and fares. To attempt to put a reliable figure on the savings was, of course, an impossibility. The only means of forming an estimate was, it seemed to him, to be found in the result of State ownership in other countries, and the figures as affecting State railways did not, as a whole, afford any ground for an optimistic view on the point. The question of whether the purchase by the State of the railways was desirable or otherwise, Mr. Calder said, in conclusion, must be finally decided on its merits from the point of view of the national welfare. State ownership in other countries had been found to be not an unmixed blessing, while naturally they all knew something of the defects of private ownership. With respect to the traders and travelling public he felt bound to express the view that the privately owned railways of the United Kingdom had, on the whole, served their interests well, and that there was very great room for doubt whether under State ownership they could possibly hope to enjoy many of the benefits which had accrued to them under the present system.

The Institute of Metals.—As previously announced, the annual general meeting of the Institute of Metals will be held at the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W., on Tuesday and Wednesday, March 11th and 12th, 1913. The meeting will commence at 3 p.m. on March 11th, and at 10-30 a.m. on March 12th. On the Tuesday, a general meeting of members will take place in the hall of the Institution of Mechanical Engineers when the report of the council on the work of the past year will be presented by the president, and the honorary treasurer, Prof. T. Turner, M.Sc., will present his report. The results of the ballots for the council for 1913 and for the election of new members will be declared, after which the newly-elected president, Prof. A. K. Huntington, will deliver his inaugural address. In the evening the fourth annual dinner of the institute will be held at the Criterion Restaurant, Piccadilly Circus, W. On the Wednesday, members will meet in the Hall of the Institution of Mechanical Engineers, when a selection of papers will be read and discussed, of which the following is a list: (1) Dr. G. H. Bailey, on "Corrosion of Aluminium." (2) G. H. Gulliver, B.Sc., on "The Quantitative Effect of Rapid Cooling on Binary Alloys." (3) O. F. Hudson, M.Sc., on "Microstructure of German Silver." (4) A. Philip, Assoc: R.S.M., B.Sc., on "The Corrosion of Distilling Condenser Tubes." (5) J. S. Glen Primrose, and H. S. Primrose, on "Practical Heat Treatment of Admiralty Gun Metal." (6) Alexander Siemens, on "Metal Filament Lamps."

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Plant for compressing gas. Phillips. 23487.
Apparatus for promoting circulation in steam boilers. Circulators, Ltd., Schofield & Sedgwick. 23576.
Internal-combustion engines. Griesbach. 26338.
Process for protecting iron surfaces from corrosion. Cowper-Coles. 26484.
Manufacture of metal tubing. Mackenzie. 29129.

1912.

Carburetters for internal-combustion engines. Burley. 131.
Spanners. Jones. 1830.
Self-propelled tractors. Bensted. 2057.
Atomisers for liquid fuel for internal-combustion engines. Kelley. 2244.
Internal combustion engines. Paterson. 2426.
Apparatus for signalling on trains and for stopping trains. Minnick. 2437.
Belt pulleys. Yoxall & Thorneycroft. 2623.
Radiators for internal-combustion engines. Morris. 2638.
Aerial turbine specially adapted for flying machines. Jumeau. 2641.
Reciprocating conveyers. Turnbull. 2713.
Rotary pumps, blowers, and motors. Lamplough. 2844.
Steam superheaters. Hollinworth. 2890.
Construction of furnace covers and doors. Winder & Muxlow. 2908.
Apparatus for drilling, punching, or stamping constructional metal members. Kolassa. 2934.
Lubricating internal-combustion engines. Best & Lloyd, Ltd., and Carpmael. 2953.
Striking gear for belts. Capello. 2962.
Valves and valve gears of internal-combustion engines. Coats and Cameron. 3485.
Valve-actuating mechanism for four-stroke-cycle internal-combustion engines. Lafitte. 3843.
Driving chains. Renold, and Hans Renold Ltd. 3888.
Automatic compressor pump applicable to the cylinder of an internal-combustion engine. Jaekel. 4062.
Bolt-making machines. Marsden, Webster, & Bennett. 4422.
Winches. Linford. 4731.
Machines for use in mining. Mavor & Coulson, Ltd., & Mavor. 4947.
Gas burners for heating or brazing metals. Fletcher, Russell, and Co., and Fletcher. 5506.
Gear wheels. Terry. 6240.
Treatment of steel ingots. Talbot. 6391.
Carburetters for internal-combustion engines. De Vallat. 7197.
Continuous annealing muffles. Gibbons & Masters. 7202.
Method and means for securing pulleys to shafts. Forster. 7501.
Endless chain motors. Kelleher. 7568.
Lathes. Feige. 7671.
Automatic coupling for railway vehicles. Smith. 7754.
Rotary air and other pumps. Feichtinger. 8079.
Regulating means for internal-combustion engines. Matti. 8080.
Tachometers. Matheson & Bruce. 8387.
Atmospheric engines. Lake. 9738.
Reversing mechanism for explosion engines. Moore. 10741.
Clutches. Prescott. 11336.
Aeroplane having automatic stability. De Bothezat. 11493.
Speedometers. Hubert. 11861.
Supports for mining drills. Newton. 12612.
Water-tube steam generators. Helm, and Sir George Croydon Marks. 13538.
Injection of water into internal-combustion engines. Tangyes, Ltd., and Robson. 13924.
Constant pressure internal-combustion motors. Schmidt. 14105.
Float feed devices for carburetters. Evans. 14734.
Process for recovering tar and ammonia from volatile products of the carbonisation of coal. Dr. C. Otto & Co. Ges. 15584.
Slide valve gears for four-stroke explosion engines. Huckel. 15994.
Machines for punching plates. Cameron, and John Cameron, Ltd. 16117.
Ship propellers. Maublanc & Lallié. 16422.
Pneumatic tools. Massmann & Tindall. 16530.
Fuel injecting apparatus for internal-combustion engines. Grunwald. 16768.
Water-softening apparatus. Fox. 16861.
Propellers for airships and aeroplanes. Ott, Fanta, & Ott. 17298.
Automatic lathe. Veritys, Ltd., and Rogers. 17638.
Steam superheaters. Schmidt'schea Heissdamp Ges. 19608.
Means of and apparatus for obtaining motive power. Hughes. 19669.
Guiding device for machines for drilling, punching, or stamping constructive members of rolled metal. Kolassa. 19760.
Automatic steam-pipe isolating valve. Loll. 19923.
Safety device for water tanks used in connection with the coolers of air compressors. Day & Windeler. 20227.
Annealing apparatus. Kammerer. 20949.
Vernier calipers. Raiser. 21065.
Grates for gas producers. Wingen. 21235.
Pistons of internal-combustion engines and packing rings therefor. Ionides. 21371.
Single-track railways. Zsinko. 21768.
Vertical shaft bearings. London. 21833.
Feed-water heaters. R. Wolf (Firm of). 22137.
Drill sockets. Morrow. 23293.
Propelling planes for airships, flying machines, and water going vessels. Wisniewski. 23941.
Steam turbine packing glands. London. 25229.
Ball bearings. Ilett & Ilett. 27435.
Gas producers. Von Kerpely. 29182.
Driving of vehicles by means of internal-combustion engines, combined with dynamos, accumulators, and motors. Pieper. 29636.

1913.

Flying machines. Fokker. 596.
Manufacture of metal tubing, channels, and mouldings. Mackenzie. 816.

ELECTRICAL, 1912.

Automatic battery over discharge preventer. Leitner. 2310.
Electrical water heaters. Shoenberg. 2522.
Electric switches. Leitner. 2747.
Electrical measuring and signalling instruments of the moving coil type. Record. 3454.
Electro-magnetic speed-varying and reversing gear. Brukwicki. 4458.
Connectors or lugs for electric conductors. Robb & Shaw. 5907.
Electric insulators. Bullers, Ltd., and Twiss. 6287.
Wireless telegraphy. Vlug. 10111.
Electric switches. Venner Time Switches, Ltd., and Griesbach. 15366.
Timing devices for operating electric switches. Chiger. 16142.
Electric furnaces. Gonnet. 19287.
Regulation of the speed of electric motors. Siemens Schuckertwerke Ges. 23341.
Electric conduit junction boxes. Terry, Bigwood, & Brotherton Tubes & Conduits, Ltd. 24492.
Ignition plugs for internal-combustion engines. Ruprecht. 28412.

METAL QUOTATIONS.

TUESDAY, FEBRUARY 18TH.

Aluminium ingot	93/- per cwt.
,, wire, according to sizes, &c. ......from	112/- ,,
,, sheets ,, ,, ... ,,	120/- ,,
Antimony ......£36/-/- to	£37/-/- per ton.
Brass, rolled	8⅝d. per lb.
,, tubes (brazed)	10⅜d. ,,
,, ,, (solid drawn)	9¼d. ,,
,, ,, wire	8½d. ,,
Copper, Standard	£63/17/6 per ton.
Iron, Cleveland	59/7½ ,,
,, Scotch	65/7½ ,,
Lead, English	£16/15/- ,,
,, Foreign (soft)	£16/10/- ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/15/- per bottle
Silver	28½d. per oz.
Spelter	£25/7/6 per ton.
Tin, block	£219/-/- ,,
Tin plates	14/6 ,,
Zinc sheets (Silesian)	£28/10/- ,,
,, (Stettin; Vieille Montagne)	£29/2/6 ,,

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WILLIAM H. FOWLER
Wh. Sc., M.Inst.C.E.

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The Hygiene of Gas Lighting and Heating.

THE superiority of electric lighting over gas is so universally accepted, on grounds of health as well as cleanliness, that it sounds almost like heresy to put forward anything in favour of the latter illuminant, and certainly the appearance of the gas-lighted room, with its stained ceilings and the demonstrable presence of products of combustion, does not appeal to the general ideas of health and sanitation. But it is only recently that the important part which air circulation plays in determining whether the atmosphere of a room is healthy or unhealthy has come to be properly understood. The presence of carbonic acid is taken invariably as a measure of the bad quality of an atmosphere as regards its suitability for human beings, and where this constituent is a product of respiration it is undoubtedly a fair gauge of the effete human products that are so deleterious. Actual experience, however, shows that when it is the output of gas flames a considerably larger quantity may be present in the air without any serious effects being observable, while actual tests have further shown that the baneful effects of humidity and carbonic acid are far less noticeable in rooms where the air is in motion. In other words, a stagnant atmosphere, even if the air is relatively pure, may be a worse enemy to health than one which, measured by the carbonic acid standard, is much worse provided it is in active motion. The body, in fact, is as dependent on the action of the skin as upon the lungs for throwing off the waste products of life, and it is this humid emanation which, entangled by the clothes, produces the feeling of discomfort that is so frequently noticeable in a badly-crowded and ill-ventilated room. For this reason it is easy to understand that a room electrically lighted and free from the dirty effects produced by gas flames on white-washed ceilings may yet be very objectionable from a hygienic point of view. Gas lighting certainly does promote air circulation, and the blackened area

on the ceiling over the gas light is as strong evidence of its influence in this direction as it is of atmospheric impurities. Though these charred remains of germs and organic matter are not artistic or desirable if they can be avoided, the question of air circulation is a more vital one, and it is in this feature that the open fireplace, with all its wastefulness and smoke objections, excels, and in which the old forms of gas stove in which high economic efficiency was secured by using the gas to heat the air of the room by convection, proved so deficient. Much improvement has been made in the later forms of domestic gas fires now it is recognised that the only satisfactory way of heating is by radiation. This involves a little sacrifice in efficiency, though it is claimed, in the latest designs of gas stoves, over 60 per cent. of the total heat of the gas may be utilised in this way. It is not probable nor is it desirable that electricity as an illuminating agent will be displaced from the pre-eminence it has secured on the grounds of cleanliness, but it is just as well to recognise that gas lighting, with all its faults, has at least one or two virtues which should be put down to its credit, and that one of the steps towards the abolition of the smoke nuisance in towns is the provision of a cheap gas supply for heating purposes, for it is extremely unlikely that electricity will ever displace it as a general agent in this direction. Some of the leading municipal authorities are coming to recognise this by reducing the price of gas, but they might do more if they would regard the gas department, not as a rate-reducing device, but as a means for distributing a heat-producing agent at the lowest cost possible. How prices can be brought down with the present high values of by-products is clearly shown by the action that has just been taken by the Sheffield United Gas Light Company, who, although a private enterprise, and working for profit, has, with a view to encouraging the use of gas for heating and power purposes, made a further reduction in its rates. Consumers using over half a million cubic feet in future are to pay only 1s. per 1,000 cubic feet, power users 10d., while the small domestic user is only asked 1s. 3d. When he can obtain gas at this price there is some encouragement for him to substitute it for coal altogether, and in so doing contribute materially to the success of the campaign against smoke which is at present so strongly marking the attitude of many municipalities towards manufacturers, who, whatever their faults, contribute only a moiety towards the smoke nuisance.

The Possibilities of Large Diesel Engines.

THE high economic efficiency of the oil engine, and particularly the Diesel development of it, has led to some rather inflated expressions of opinion as to its future prospects. Not only is a distorted perspective taken of what economic efficiency stands for, but enthusiasm is apt to close its eyes to facts. Not long ago British engineers were rather taken to task by some of its professional mentors for alleged lack of enterprise in the direction of large oil engines, and we were informed of the wonderful successes that were being scored in Germany and elsewhere, but, as Mr. Ferranti remarked in the course of his recent Watt lecture at Greenock, we have heard very little of the failures that have occurred and are repeatedly occurring with these large Diesel engines. One of the biggest experiments with them was to fit a 12,000 h.p. German battle-ship with motors of this type of such a size that the whole of the power was to be developed in six cylinders; but in making a test of three of them an explosion occurred, which wrecked part of the engine, killed several men, and caused a serious fire, with the result that the naval authorities abandoned the attempt and decided to substitute a full-power steam turbine plant instead. The fact is, that for large power units of the internal-combustion type, oil does not offer as great advantages as gas, and the Diesel type more particularly demands mechanical refinements of a high order to give the high compression which is necessary; and this refinement, in the shape of minute clearances, is very liable in practice, as our columns have shown, to lead to serious breakdowns even when every care is exercised in regard to manufacture and attendance. The Diesel engine possesses many merits, and we have no desire in any way to belittle them or overlook its high thermal efficiency. But it is a long way behind the large gas engine even from the constructional point of view, and the large gas engine itself is far from perfect. The main difficulty in the application of large gas engines to marine propulsion lies in the producer, the chemistry as well as the control of which is more complicated than is generally thought, though the difficulties are being slowly overcome. These conquered, the application of large gas engines to marine propulsion would receive a great impulse, for they would derive their fuel supply from the same inexhaustible store as the steam engine, namely, coal, and not from a fuel such as oil, the high price of which must always handicap the motor in which it is used, however great its thermal efficiency, except in favoured positions or services. For the fact cannot be overlooked that the world's total supply of oil is but an insignificant portion of that lying in the coal beds, and if all of it were used for power purposes —an assumption impossible of attainment owing to the demands for petrol and other oils—the supply could only meet a fraction of the demand

Disastrous Flywheel Burst.—A terrible accident is reported from a large steelworks at Wetteren, in Belgium. A number of men were at work when a huge flywheel, weighing about 15½ tons, burst, and the pieces were hurled in every direction. Three workmen were fatally injured, and a number of others badly hurt. The machinery hall was wrecked, and 300 men have been thrown idle.

Microscopic Effects of Strain in Metals.— A lecture on "Microscopic Effects of Strain in Metals" was delivered by Dr. F. E. Rogers at a recent meeting of the Sheffield Society of Engineers and Metallurgists. He pointed out the value of straining as a means of studying the structure of metals—particularly steel—and as an accessory to the usual etching methods employed by microscopists. The method was largely used in the laboratory and was of great assistance. It threw light on the relative hardness of the constituents which were seen under the microscope. Dr. Rogers showed how a systematic knowledge of the subject might be usefully applied by the practical steel microscopist. Strain effects in steels of various composition and treatment, and in iron, lead, and brass were studied and illustrated. The effects typical of static stress, of fatigue under alternating stress and shock, were dealt with. It was shown that the strain effects might take different forms in different cases, such as crystalline cleavage ("slip-bands"), intergranular strain, Neumann lamellæ, partial critical transformation (as in the cases of austenitic steels near the limit of composition beyond which martensitic structure is obtained), and twinning. Fracture might result as the development of any of these phenomena. Lüdeds' lines were explained. The lecturer said the straining method was a valuable addition on the one hand to etching methods, and on the other was at least as valuable, and often much more so than any microscopic hardness test, because, with practice, one became able to recognise as typical the various strain evidences in each constituent, and the effects of varied treatments upon them.

MODERN CONDENSING SYSTEMS.*

BY A. E. LEIGH SCANES, M.A.

(*Concluded from page* 202.)

Circulating Pumps.—It is apparently thought by many people that there is little room for choice under this heading; that it is only necessary to fix the water quantity and head required, and proceed to make or order a pump. This, unfortunately, is the view taken by large numbers of customers who do not avail themselves of expert advice. They are apt to look only at the initial outlay, and overlook running efficiency and reliability. A short study of the design of centrifugal pumps, however, will show that for any given set of conditions and design of pump, one set of characteristics will give the best results. That is to say, the speed at which the pump is to work is fixed for a maximum efficiency. The first point to settle then, in the choice of a pump, is the most suitable speed having regard to all conditions of service. The next point is to consider if it is advisable to run this pump from the same motor or engine which is to drive the air pump. With reciprocating air pumps this is usually done with the help of gearing. This arrangement, however, is not usually liked, as even with the best design a certain amount of noise is unavoidable, which is most noticeable with a turbine installation. The best alternative is a rotary air pump which, when possible, should be run at the same speed as the circulating pump, all gears being avoided.

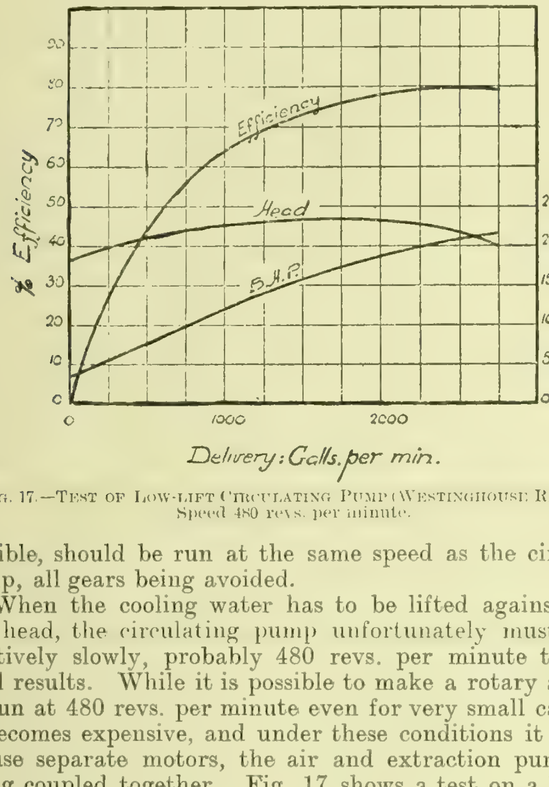


FIG. 17.—TEST OF LOW-LIFT CIRCULATING PUMP (WESTINGHOUSE RATEAU). Speed 480 revs. per minute.

When the cooling water has to be lifted against a very low head, the circulating pump unfortunately must be run relatively slowly, probably 480 revs. per minute to obtain good results. While it is possible to make a rotary air pump to run at 480 revs. per minute even for very small capacities, it becomes expensive, and under these conditions it is better to use separate motors, the air and extraction pumps then being coupled together. Fig. 17 shows a test on a Westinghouse-Rateau low-lift pump, designed for a low speed. When a cooling tower must be used and the head against the circulating pump is 30ft. or more, a high speed can be utilised and all the pumps direct coupled, it often being advantageous to drive them by a low-speed turbine as shown in Fig. 10. Even with a high head the efficiency of the water pump will be relatively low, about 65 per cent. for a speed of 2,500 revs. per minute, but the advantages of a self-contained unit, which does not depend on the main plant for power, usually more than compensates for this and the additional initial outlay involved.

Extraction Pumps. — The desire for high efficiency in every detail can be carried to excess, and in the end defeat its own object. This in the past has often been the case with condensed steam extraction pumps for use with surface condensers. To save 1 h.p. to 2 h.p., 4 or even 6-stage pumps have been built running at about 1,000 revs. per minute. When it is considered that if one of the extraction pumps should fail the whole plant will be seriously affected, if not shut down with some types of air pump, it is obvious that simplicity of design and reliability is essential. The British Westinghouse Company has developed a single-stage pump running at a high speed which gives a sufficiently good efficiency, from 40 per cent. to 60 per cent., according to size. A section is shown in Fig. 18 which is self-explanatory. These pumps can either be horizontal and direct coupled to the air pump, or, if the latter is coupled to the circulating pump and running at too low a speed, they can be driven by a small vertical motor, which gives an ideal arrangement, as the pump itself can be sunk well below the condenser floor level, ensuring a good head of water on the inlet side. Much trouble has been caused by not allowing sufficient head to overcome the pipe friction from the condenser and to give the necessary velocity into the impeller. A sure symptom of this is intermittent discharge. Should an accident stop this pump, a Leblanc air pump will take up its duty, and remove the condense with a very slight fall of vacuum.

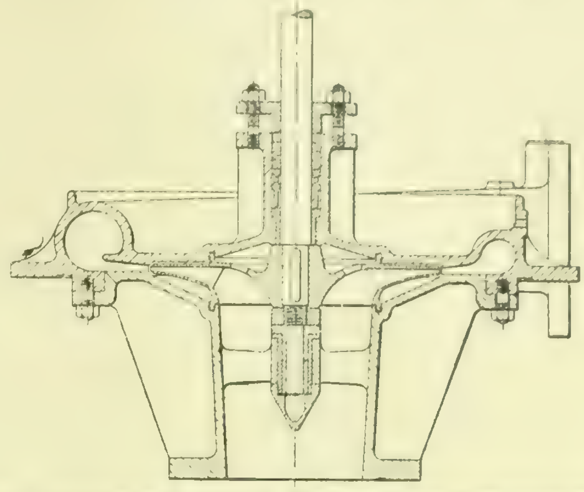


FIG. 18.—DIAGRAM OF VERTICAL EXTRACTION PUMP (WESTINGHOUSE).

Vacuum Traps.—When it is necessary to have a condenser placed so that there is a fall in the exhaust pipe to the engine or turbine, an efficient vacuum trap must be fitted to remove the water which collects and which would ultimately obstruct the free passage of the steam. A very simple and effective type is manufactured by Mr. John E. L. Ogden, and is illustrated in Fig. 19. It consists of a cylinder divided into two compartments B, B, and supported at the centre on trunnions A. The ends are connected to the vacuum space, and the drainage water falls by gravity into each end alternately, causing the cylinder to tip from side to side, a simple valve C releasing the water when the slide-valve cuts off the vacuum connection.

Jet Condensers. — Jet condensers may be used when the supply of cold water available, either from natural sources or from a cooling system, is suitable for boiler-feed purposes.

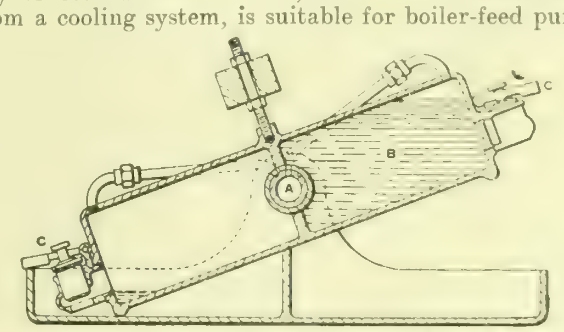


FIG. 19.—DIAGRAM OF CONTINUOUS-DRAIN VACUUM AND STEAM TRAP (OGDEN).

Even when this is not the case, but the water is of a quality which would rapidly "scale" or "pit" the tubes of a surface plant, jet plants can often be advantageously used in conjunction with a purifier for feed purposes. The power absorbed by the pumps is usually higher than for a surface plant, although the actual water quantity required is considerably less, the excess power being due to the water being extracted from the condenser body against the vacuum head (which is approximately 32ft.) in addition to any external pressure. The air pump must also be larger to deal with the air liberated from the water, usually not less than 2 per cent. of its volume at atmospheric pressure.

The earlier forms of jet condensers were of the parallel flow

* Paper read before the Institution of Mechanical Engineers, February 14th, 1913.

type, in which the steam enters at the same end of the condenser as the cooling water. The air is extracted at the opposite end, and is obviously at the temperature of the discharge water. A marked improvement came with the introduction of the counter-current type, one form of which is illustrated

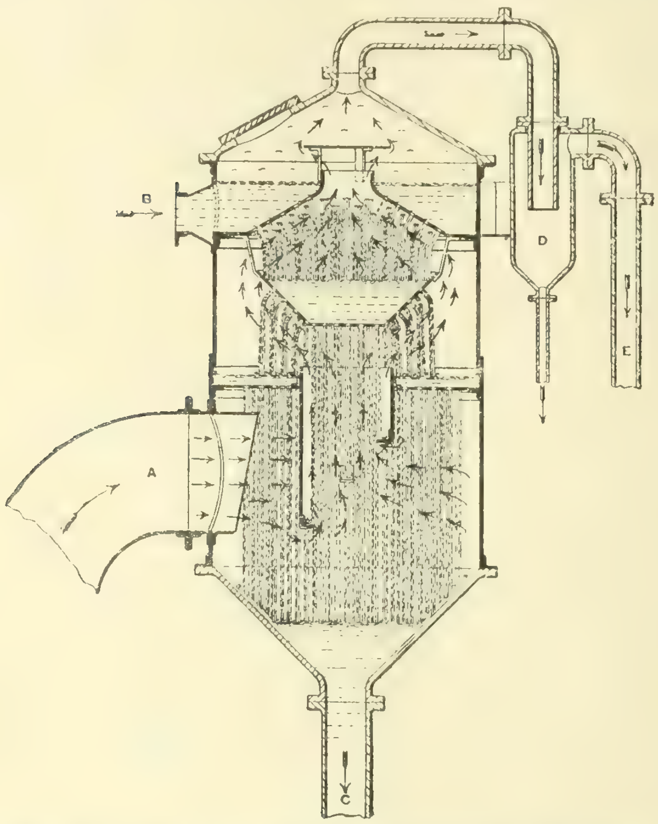


FIG. 20.—DIAGRAM OF COUNTER-CURRENT JET CONDENSER.
A, steam inlet; B, water inlet; C, water and condenser outlet to extraction pump or barometric leg; D, water separator in air-pump suction; E, air-pump suction.

in Fig. 20. The steam here enters near the bottom and the water at the top, whence it flows over a series of trays or through a series of holes in fine streams. The air is removed from the top of the shell where it is coldest, owing to contact with the entering cooling water through which it passes, and the size of the air pump required is, therefore, smaller than in the parallel flow type.

It is curious how improvements in any apparatus frequently revert to a modification of earlier designs. The Westinghouse-Leblanc multiple-jet condenser is an example of this. Turning to Fig. 21, which illustrates this plant, we see that the water and steam enter at the top, but with several important improvements. The water does not flow by gravity through a number of small holes, which are liable to choke up, but is sucked in by the vacuum at high velocity through a number of nozzles of ample size, which have a spiral vane in the centre of the nozzle to give the water a rotary movement which effectively breaks it up to form as large a surface as possible.

The most important point, however, is the cone under the water-injection nozzles, Fig. 21. The water passing through this at a high velocity gives the air a first compression into the chamber D. The disadvantage of this air being at the temperature of the discharge water is neutralised by the cooling effect of the Leblanc air pump. The condensed steam and water is removed by the centrifugal pump C, which is on the same shaft as the air pump, one motor or engine only being needed to work the plant. The pump C is specially designed to work against the high vacuum head of the condenser, and is so arranged that no air lock can be formed. The external head on the extraction pump is normally from 0ft. to 35ft., according to conditions, but in special cases even higher heads can be dealt with. The great advantage of this type is immediately apparent, as it can be placed directly below a turbine plant without intermediate or bend exhaust pipes, ensuring a straight flow for the steam and no loss of vacuum between the exhaust outlet and the condenser. The space occupied by this plant is much smaller than is required for any other similar type, owing to the compactness of the rotary pump.

The vacuum efficiency is not less than 98 per cent. for turbine work, the average terminal temperature difference between the theoretical temperature of the vacuum and the outlet water temperature is about 4° Fah., and in many cases this figure can be further reduced and sometimes eliminated, that is to say, the theoretical vacuum attained. The latter condition necessitates a very tight system, and low-seal water temperature in the air pump.

Where head room does not permit of the plant being placed immediately below the main unit, a side exhaust can usually be adopted, which arrangement was adopted by the Westinghouse Company at the Metropolitan Railway Company's Power Station at Neasden. This plant will be eventually composed of five 5,000 kw. Westinghouse-Rateau impulse turbines, exhausting into five Leblanc jet condensers. Each condenser is designed to deal with 70,000lbs. of exhaust steam per hour at a vacuum of 28·1in., the temperature of the injection water being 82° Fah., 9,000 galls. being circulated per minute. Two of these sets are now running under full load conditions, and the guaranteed vacuum is easily maintained. The author thinks it may fairly be claimed that such results as these are the best that could be obtained under commercial working conditions.

A detail of design of great importance in low-level jet condensers, particularly when working with reciprocating engines, is the vacuum-breaker, F, Fig. 21. Many serious breakdowns in the past have been due to complicated

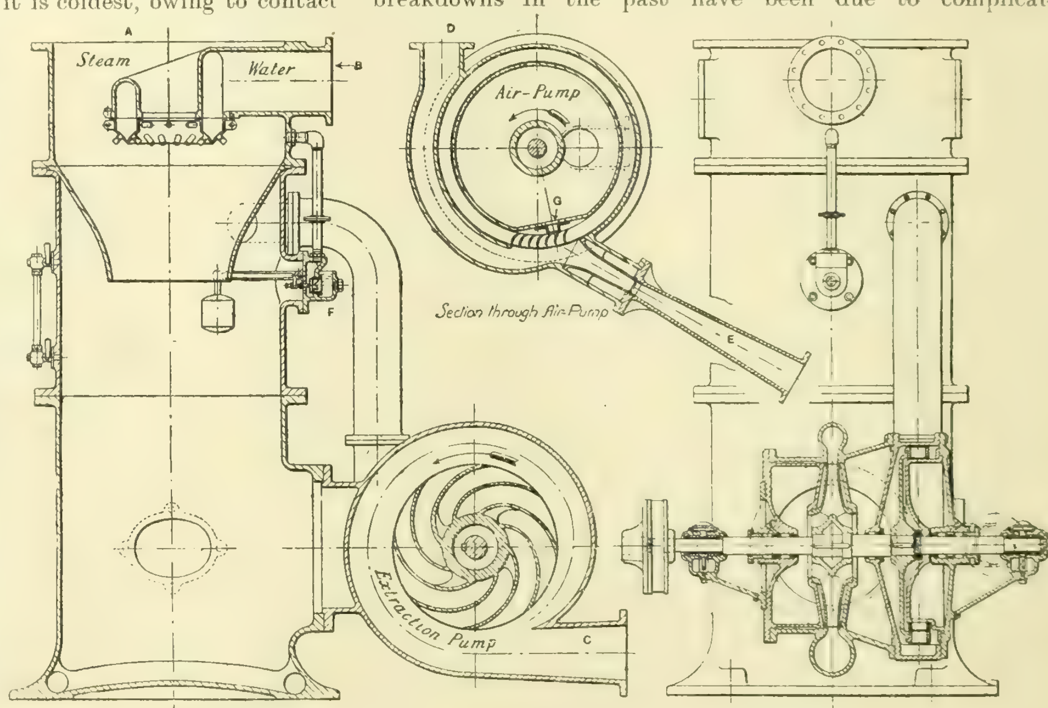
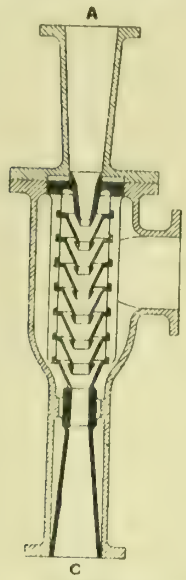


FIG 21.—DIAGRAM OF MULTIPLE JET CONDENSER (WESTINGHOUSE-LEBLANC).
A, steam inlet; B, water inlet; C, water discharge from extraction pump; D, air-pump suction; E, air-pump discharge; F, vacuum breaker; G, water guide nozzle.

mechanism failing to act efficiently in emergency and allowing the cooling water to enter the low-pressure cylinders. In the Leblanc jet an extremely simple and effective breaker is employed which eliminates this risk. For large plants two or more breakers are fitted, each capable of destroying the

vacuum in a few seconds. Should the pumps stop for any reason, the air pump also acts as a vacuum-breaker, the air having a free entrance to the condenser through the air pump discharge diffuser.

It has been the author's experience that troubles have been hastily attributed to back-flooding of the condenser,



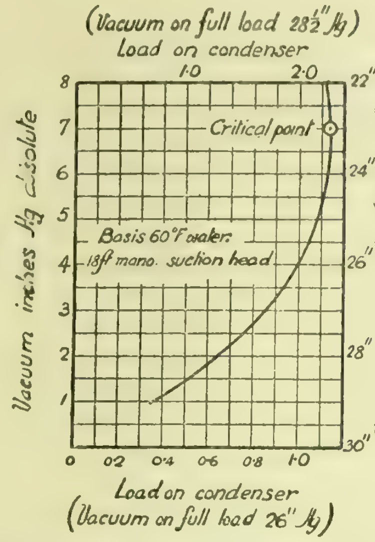


Fig. 22. Fig. 23.

Fig. 22.—Diagram of Ejector Condenser.
A, water inlet; B, steam inlet; C, natural head of water of about 15 ft. is necessary to work this plant, or a rotary pump to give the necessary head.
Fig. 23.—Critical Point in Jet Condenser.

which have afterwards been traced to more obscure causes. In several cases when the engine has been running on light load with a very high vacuum of, say, 28·5in. when changing over to "atmosphere," knocking has occurred in the low-pressure cylinder due to rapid condensation caused by the low temperature of the cylinder walls. Great care should be also taken not to have a rise in the exhaust pipe between the engine and the condenser, or if unavoidable, a large and efficient vacuum and low-pressure trap should be provided.

Barometric Jet Condensers.—These are very similar to the low-level type, with the exception that the hot water and condensed steam are removed by means of a barometric leg instead of an extraction pump. The advantage is that the risk of back-flooding through failure of the extraction pump is eliminated. The disadvantages consist of greater expense, more room occupied and loss of vacuum between the condenser and main unit due to the abnormal length of exhaust-pipe necessary. This loss may vary betwen 0·25 and 1·0 of mercury. In the majority of cases a low-level jet is to be preferred. The only condition where a barometric plant is advisable is when the cooling water is at a level which does not necessitate an injection pump.

Simple Jet Condensers.—For very small steam quantities, ejector condensers are frequently employed. Fig. 22 shows one of the best forms of the older designs. A great objection of this type is its limited air capacity, which depends on the quantity of water passing through the condenser. To overcome this objection the Westinghouse-Leblanc simple jet condenser, Fig. 24, was designed, working on the principle of the air pump. This plant will remove air in the ratio of from four to five times the water volume, giving a vacuum efficiency nearly as high as the multiple jet.

Evaporative Condensers.—The author does not propose to deal with these, as they are quite unsuitable for the high vacua now in vogue, owing to the impossibility of keeping them reasonably air-tight for any length of time.

A very important condition in the working of a condenser which draws its cooling water by means of its vacuum is frequently overlooked by users, namely, the maximum overload which can be put on the condenser without it entirely shutting down. It is obvious that, as the vacuum falls, less water will be drawn in, the effect being cumulative until enough does not pass to condense the steam, the vacuum entirely failing. Table III. shows how this may be calculated, and Fig. 23 is a curve plotted from the table. Arrangement can always be made so that the critical point is beyond the highest steam consumption possible, if the maker is consulted with that view. Many unexplained failures could probably be traced to this cause.

APPENDIX I

Vacuum Efficiency.—This is the percentage of the theoretical vacuum corresponding to the temperature of the condensed steam discharged (as obtained from steam tables) which is maintained at the inlet to the condenser.

Example:
Hot-well temperature, 90·0° Fah.
Corresponding vacuum, 28·6in.
Vacuum at inlet, 28in. = 98 per cent. of 28·6in.

This term must not be confused with condenser efficiency, which refers to the volume of water required to condense a given quantity of steam compared with the theoretical quantity necessary.

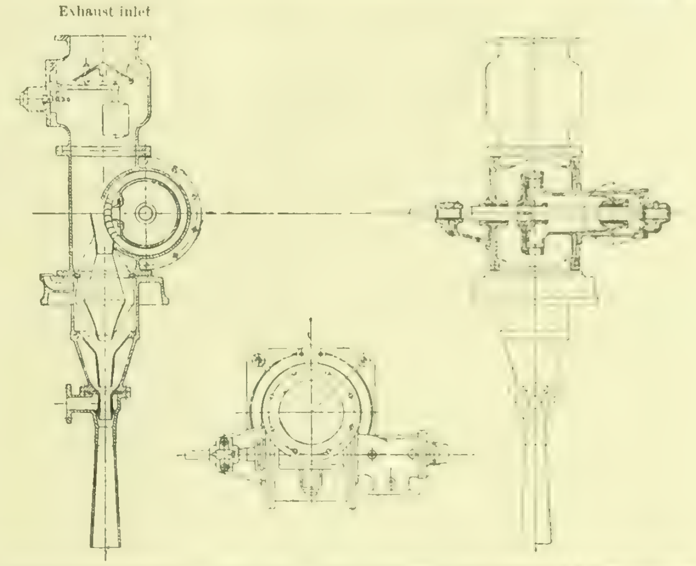


Fig. 24.—Diagrammatic Sectional Arrangement of Simple Jet Condenser Plant (Westinghouse-Leblanc).

APPENDIX II.

Partial Air Pressure.—Dalton's law of partial pressures of gases states that if two or more gases (such as air and steam) are enclosed in a vessel, the total pressure exerted on the

TABLE III.—*The Critical Point in a Jet Condenser.*

Basis—Water 60° Fah. at inlet and 18ft. mano. suction head.

Vacuum in. Hg. (Bar. 30in.)	Vacuum Head (ft. of H_2O) h.	Mano. Suction Head (ft.) h_1	Head causing Flow $h - h_1$.	$\sqrt{h - h_1}$.	Inlet Water Temp.	Outlet Water Temp.	Vacuum Temp.	Ratio water steam.	Water Quantity	Steam Quantity	Per cent. of Full [illegible]	
					Fah.	Fah.	Fah.		[illegible]	[illegible]	[illegible]	[illegible]
29	32·9	18	14·9	3·86	60	75·1	79·1	70·4	1	0·014	27·5	54·6
28·5	32·3	18	14·3	3·78	60	87·8	91·8	37·8	0·98	0·026	49·5	100
28	31·7	18	13·7	3·7	60	97·2	101·2	28·1	0·96	0·034	65	131·5
27	30·6	18	12·6	3·55	60	111·1	115·1	20·4	0·92	0·045	85·6	173
26	29·5	18	11·5	3·39	60	121·5	125·5	16·75	0·88	0·053	100	202
25	28·3	18	10·3	3·21	60	129·8	133·8	14·7	0·83	0·057	108	217
24	27·2	18	9·2	3·04	60	136·8	140·8	13·3	0·79	0·059	113	228
23	26·1	18	8·1	2·85	60	142·9	146·9	12·25	0·74	0·06	114	232
22	24·9	18	6·9	2·63	60	148·3	152·3	11·4	0·68	0·059	113	228

walls will be equal to the sum of the pressures proper to each gas at the same temperature. Therefore, in a condenser the total pressure is the pressure of steam at the temperature of the mixture plus the pressure of such air as is present at the same temperature.

APPENDIX III.

Mean Temperature Difference.—For counter-current condensers the mean temperature difference (δ) is obtained from the formula:—

$$D = T_4 - T_1$$
$$B = T_3 - T_2$$
$$\delta = \frac{D - B}{\text{Log}_e \frac{D}{B}}$$

In practice it is sufficiently accurate to take $T_3 = T_4$, which gives a lower result for δ.

T_1 = inlet water temperature.

T_2 = outlet water temperature.

T_3 = inlet steam temperature at top of condenser.

T_4 = final temperature at bottom of condenser.

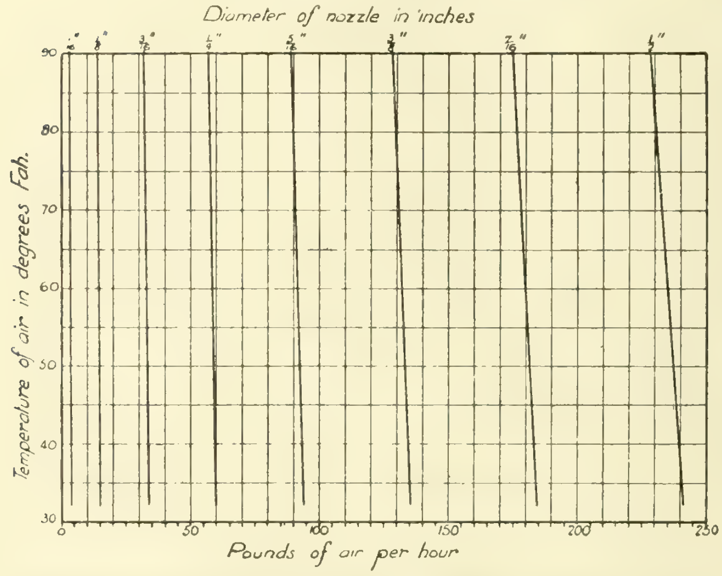


FIG. 25.—WEIGHT OF AIR PASSING THROUGH A PROPERLY SHAPED NOZZLE.

APPENDIX IV.

Weight of Air passing through a Nozzle.—The weight of air passing through a properly designed nozzle may be calculated as follows (Leblanc):—

$$W = 384 \cdot 2 \frac{P}{\sqrt{T_B + 273}}$$

$$V = 11 \cdot 25 \sqrt{T_{B1} + 273} \times F.$$

W = weight in grammes per cm^2 area of neck.

P = atmospheric pressure = 1 kg. per cm^2.

V = volume in litres at atmospheric presssure.

T_B = atmospheric pressure in ° C.

F = area of nozzle neck in cm^2.

In English notation:—

W = lb. weight per hour.

A = area of nozzle neck in square inches.

T_B = atmospheric temperature ° C.

$$W = \frac{20330A}{\sqrt{T_B + 273}} \quad (\textit{See Fig. 25.})$$

THE ADVANTAGES OF LIQUID FUEL.

AT a meeting of the Wolverhampton and District Engineering Society, Mr. W. D. Kirkpatrick, of Kermodes, Ltd., Liverpool, read on behalf of Mr. J. J. Kermode a paper on "Liquid Fuel and its Burning for the Production of Power." After dealing with the methods of production and application, Mr. Kirkpatrick passed on to the economic conditions involved in the use of liquid fuel. He declared that the consumption of oil was perfect, provided due care in the design of the apparatus was taken. Its calorific value might be taken as 50 per cent. better than coal; perfect and instant control of the fires might be obtained; they could be started or shut down at a moment's notice, and unlike all coal fires, no fuel was expended and no heat lost when the oil fuel supply was stopped. In the case of steamships, the advantages might be enumerated as steady steaming, fires never dirty, no fires to clean and consequently no tube cleaning. From the effect of dirty fires and boiler tubes fouled with soot and ashes, quite 12½ per cent. of the steam was lost upon a voyage between points seven days apart. The loss of speed was, therefore, considerable. Other advantages were the reduction of bunker space to about five-eighths of that required for coal and the reduction of the number of fire-room hands. Moreover, the bunkering of the largest vessels could be effected cleanly and silently in a few hours, as hundreds of tons of fuel could be pumped into the bunkers in a very short time.

The lecturer next dealt with the application of oil fuel to industrial processes. He admitted oil cost more initially, but more than ample compensations were secured. In foundry practice the use of oil fuel would reduce the time taken to dry large cores. Thus, there was not merely the time saved on the operation to be considered, but the all-important factor of the speed with which moulds could be ready, castings completed, and goods dispatched. On the assumption that a foundry floor was available 1½ times as often owing to the employment of liquid fuel, the cost of fuel hardly counted, as it was overshadowed by the many advantages gained. There was not a process, he declared, where heat was required where the operation of heating could not be more rapidly accomplished with oil fuel than with coal, and the absolute control over temperature, absence of smoke, smell, soot and clinker, were points in favour of liquid fuel, and the healthier conditions of working which its employment made for. Oil fuel could be used for the most delicate operations. In many of the metal trades, the number of sheets of metal spoiled in the rolls owing to the plates being imperfectly heated was considerable. Coal fires were often irregular, despite careful attention, but the automatic oil fire would ensure that every unit was uniform and the percentage of wastage would be reduced to a trifling amount.

The lesson of the coal strike in the early part of 1912 would not readily be forgotten, and the heads of many municipal electric power stations had under consideration at the present time the desirability of being able and ready to use liquid fuel should the necessity again arise in the near future. There was no doubt that the oil companies missed a great chance to establish oil permanently for certain industrial furnaces at that time, when the raising of the price of oil prevented its more general adoption. In conclusion, Mr. Kirkpatrick expressed the belief that, when transport facilities were available, the present price of residuum oil would rapidly decline, for it was only natural to expect that producers were at present only shipping the better paying products, viz., motor spirit and kerosene distillates, and there must necessarily be large quantities of residuum in stock at the wells pending transport arrangements.

Death of Sir William Arrol.—We regret to announce the death of Sir William Arrol, the eminent engineer and principal partner in the firm of Sir William Arrol & Co., Ltd., of Dalmarnock Ironworks, Glasgow, which took place at Ayr on the 20th inst. Sir William, who was in his 74th year, was in the fullest sense of the term a self-made man. He began work when nine years old as a piecer in a cotton factory. Some years afterwards he started work on his own account. From minor jobs he gradually worked his way up to bigger things, and at length he had a full opportunity of showing his quality as an engineer when he was given the contract for the construction of a railway bridge over the Clyde at Bothwell. This bridge made his reputation, and he was already engaged in some preliminary work connected with the Forth Bridge when the destruction of the Tay Bridge in the great gale of 1879, brought him another immense undertaking. His chief achievement was the Forth Bridge, on the completion of which, in 1890, he received his knighthood.

THE DESIGN OF HOT-WATER SUPPLY SYSTEMS TO MINIMISE CORROSION.

IN a paper on the "Durability of Welded Steel Pipe," reprinted in our issue of April 21st, 1911, see p. 473, Vol. XXVII., Mr. F. N. Speller, of the National Tube Company, Pittsburg, discussed the results of investigations on the relative corrosion of iron and steel in service, and the influence of the dissolved gases (oxygen and carbonic acid) in water and a scheme was suggested for rendering the water practically harmless by re-

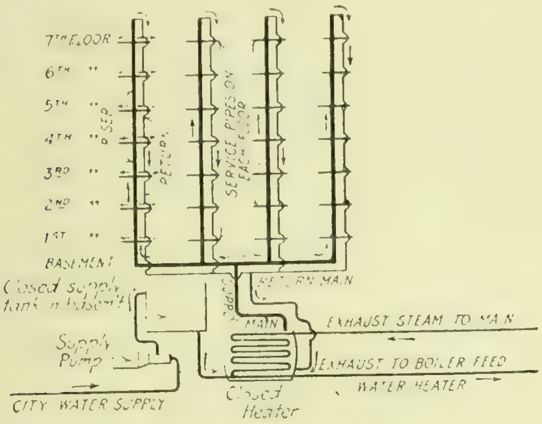


FIG. 1. UNDERFED CLOSED SYSTEM.

moving the air after heating. In the paper referred to, the writer pointed out, first, that the superiority claimed for "genuine" wrought-iron pipe had not been proven by comparative tests in service; on the contrary, the numerous cases which are on record (and which have been largely added to since that time), show conclusively that where both iron and steel have been used together in water lines, the wrought iron pits just as badly as the steel under the same conditions.

The cause of this pitting is now generally recognised to be due to galvanic action between impurities on the surface of the metal, especially mill scale and rust. The leading authorities now seem agreed that corrosion is practically independent of the composition of the metal, provided it is reasonably uniform (as the steel used for welded pipe must necessarily be if it welds without developing injurious defects). In order to have continued corrosion, oxygen must be present in solution; the removal of this oxygen has been found to greatly lessen corrosion.

In his recent report of researches along this line, Dr. W. H. Walker, Director of the Research Laboratory of the Massachusetts Institute of Technology, describes one of his experiments thus: "Two coils made up from pieces taken from the same length of pipe were each fed with water from the same source at the same temperature. In one case the water was heated to 85° C. in an open tank, while in the other the water was heated to the same temperature in a closed tank. The feed water contained on the average 5·85 c.c. of oxygen per litre, and passed through each coil at the rate of half-a-gallon per minute. After running 1,750 hours the coil fed with water heated in an open tank had lost 22 grammes, while the coil fed with water heated in a closed tank had lost 155 grammes. In neither case was the oxygen completely removed; if the water in the open tank had been gently boiled, corrosion in the coil fed with this water would have been completely prevented."

These results again indicate that the intensity of conditions have much more to do with corrosion than anything else; so much so that the same material used as a pipe in a hot-water heating system, where the water is practically free from oxygen and unchanged, should last 50 years or more, while in a closed hot-water supply system it may only last five or six years. This principle of heating and freeing the water from dissolved oxygen, by which it seems possible to prolong the life of standard welded pipe several times, is surely worthy of careful consideration in designing piping systems which are subject to corrosion.

A recent investigation, undertaken by Mr. Speller and recorded by him in a recent issue of "Engineering News," has developed interesting points in regard to the present practice of laying out hot water supply systems. The influence of the arrangement of the piping on corrosion seems to be quite marked, depending on whether the gases are liberated before the water enters the distributing system or not, although the separation of these gases is only partially accomplished under the best conditions. Large installations were considered, such as hotels, large apartment and office buildings, where on account of the great quantity of hot water used, serious trouble would be most likely to occur.

The hot-water supply systems found in these buildings differ in many details, but may be divided into two classes, according to whether the main vertical distributing lines are supplied from a common horizontal main in the basement, or from a similar horizontal distributing main above the level of the highest fixture near the roof. These types of installations are illustrated, diagrammatically and without detail of any kind, in Figs. 1 and 2.

The underfed system is characterised by a number of independent risers and return-risers, each supplying a separate section of the building. These risers are rarely vented at the top, and consequently the hot water is always supersaturated with air when the system is in continuous use. This is a good example of the closed type of heating so designed that it would be very difficult, if not entirely impracticable, to vent so as to remove the gases before the water is used.

The system illustrated by Fig. 2, on the other hand, is radically different in this respect, and to a considerable extent, although not completely, allows the escape of dissolved gases to the atmosphere at the highest point before the water is distributed throughout the system and returns to the heater. Since all the water used passes up through one riser a vent must be provided, otherwise trouble due to the trapping of air in the upper lines would probably be experienced. It would seem to be a very simple matter to almost completely free the water from dissolved gases with such a system, by putting a simple air-separating device at the upper end of the main riser, as indicated at the point A in Fig. 2. To obtain the best results the water should be heated to about 200° Fah., using an inter-cooler, if desired, to reduce the temperature after leaving the air-separating chamber.

Only general principles affecting the life of the piping system have been discussed; the details necessary to carry out these principles in practice will, of course, require thought and expert knowledge of design on the part of practical

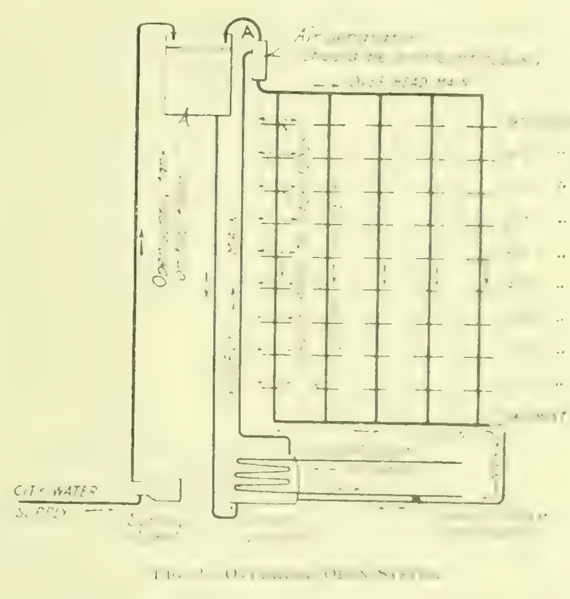


FIG. 2. OVERHEAD OPEN SYSTEM.

engineers having to do with heating and plumbing. With pure water the percentage of dissolved gases is proportionately high, so that the benefit to be expected from such treatment when thoroughly carried out and maintained would probably be very marked. Several cases investigated, where large systems of hot-water supply lines have suffered serious damage in six or eight years, have all occurred in buildings equipped with closed heating systems. So far serious trouble has not been found in systems of the open type where any attention has been given to venting. Although the significance of adequate venting of such systems does not seem to be appreciated by architects and engineers, for in some cases [illegible]

vents were provided, the practice was to keep them closed except when trouble with air-hammer was experienced.

Engineers and architects have perhaps hesitated to make changes in the closed system of heating without more practical evidence of a substantial character, the scientific study of corrosion being all new ground. The author hopes to see a free discussion on the part of those who have most experience in such work, so that the best system of design may be developed for such installations with due regard to prevention of corrosion.

STARTING AND SPEED CONTROL OF INDUCTION MOTORS.*

BY F. C. ALDOUS.

IN the following paper 2 and 3-phase motors only are considered, which may be taken as having the same characteristics for starting and speed control. Two types of motor will be considered, (1) the squirrel-cage induction motor with permanently short-circuited rotor, (2) the slip-ring induction motor with phase-wound rotor and external resistances.

1. **The Squirrel-cage Induction Motor.** — The squirrel-cage motor has a fixed rotor resistance, and with a given stator voltage can, therefore, only run at one speed at any particular load. At no load it runs synchronously with the magnetic field of the motor. As the load increases the rotor current, and, therefore, the voltage drop in the rotor, increases, almost in proportion to the load. This voltage is generated because the speed of the rotor is below that of the magnetic field. The amount by which the speed of the rotor is less than the synchronous speed is known as the slip, generally expressed as a percentage of synchronous speed, and increasing almost in proportion to the load. It has a value of a few per cent. at normal load. The correct proportioning of "slip" is a most important point in the design of squirrel-cage machines, and will be referred to later.

2. **The Slip-ring Induction Motor.** — The slip-ring motor differs from the squirrel-cage motor in that the speed can be varied by means of external resistances, which are connected in series with the rotor through the slip rings. When these are short-circuited, the motor, like the squirrel-cage motor, runs at a speed slightly below synchronous speed, but can be reduced to any lower speed by varying the resistance in the rotor circuit.

The type of motor which is most suitable for any particular service is determined by the conditions of the load, which may be classed as follows: (1) Constant speed, where after being started the motor has to run at one speed only. (2) Variable speed, where the motor may operate at more than one speed.

1. **Constant Speed.** — It is well known that many engineers are strongly prejudiced in favour of the slip-ring induction motor, as opposed to the squirrel-cage motor. On small circuits, and especially on mixed power and lighting circuits the prejudice is a natural one, since the effect of starting a squirrel-cage motor of comparatively large output is to draw momentarily from the line a heavy current, which causes a drop of voltage and a temporary dullness of any lamps in the vicinity. With a slip-ring motor the starting current can be more gradually applied, and its maximum value is not so great as would be the case with a squirrel-cage motor. Where, however, these restrictions are not in force, the squirrel-cage motor has many advantages not possessed by the slip-ring motor, and can be used in many cases where the slip-ring motor would be impossible. Since it has no moving contacts it requires less attendance, so that the maintenance charges as well as the first cost are a good deal lower than with slip-ring motors. Squirrel-cage motors can be used in practically all cases where they normally run at a constant speed, and up to a size such that their starting current shall not cause undue disturbance to the voltage of supply.

The energy absorbed in starting a squirrel-cage motor exceeds that required for a slip-ring motor, but this can be neglected when compared with the total energy absorbed by the motor when running for long periods under load. The maximum size of a squirrel-cage motor that should be used on any particular circuit is dependent upon the minimum total power of the generating plant which would be running when the motor is started up; on the voltage regulation of this plant; and on the dimensions of the feeders to the motor As a rough rule it may be said that when running off the mains of a supply company, the horse-power of a squirrel-cage motor which has to start on heavy load should not exceed 5 per cent. of the k.v.a. of the total minimum generating plant, or 10 per cent. if it starts on light load. On a large power system lower figures than the above would have to be taken. On a self-contained system, such as a group of collieries with their own generating plant, these figures may be easily doubled, since the permissible voltage drop will be greater.

Variable Speed. For variable speed work the slip motor is generally preferred to the squirrel-cage motor. In order to obtain speed control on a squirrel-cage motor, the motor must be built with a rotor of high resistance, lower speeds being obtained by reducing the voltage of the stator. It follows that to obtain a certain torque at a reduced speed the stator current is increased. If, therefore, the motor runs for long periods at a reduced speed, the increased stator current, as well as the heating effect of the high-resistance rotor, combine to increase the heating of the stator, so that a motor is required larger than if a slip-ring motor were used. Where, however, the motor operates at low speeds only for short periods, or where the use of slip-rings is objectionable, squirrel-cage motors may be used with advantage, especially in small sizes.

If good speed regulation is required at several speeds, as for machine-tool driving, then if a simple slip-ring motor were used the speed regulation would be bad at low speeds. Again, if full-load torque is required for long periods at reduced speeds, as in the case of a motor driving a compressor or a plunger pump at different speeds, there would be a constant loss of power in the regulating resistances when running at low speeds if a slip-ring motor were used. In this case a multi-speed motor, which is generally of the squirrel-cage type, is preferable, wound so as to give, by changing the number of poles, two or more economical speeds. For 2-speed motors with a ratio of speeds 2 : 1 this can be done by using one winding, which is connected for one number of poles for the low speed, or for half that number for the high speed. For other ratios, or for more than two speeds, it is necessary to use two windings, which might, for instance, be connected for six, eight, 12, or 16 poles, the corresponding speeds on a 50-cycle circuit being 960, 720, 480, and 360 revs. per minute, giving a very useful range for variable speed work. Where suitable speeds cannot be obtained by the use of multi-speed motors, this can often be done by means of "cascade" control.

Fan-driving. — The electrical driving of ventilating fans for mining work is an important example of variable speed drive. During the development of a new pit a fan may have to run for long periods, sometimes for years, at a speed lower than its ultimate speed. Where this is the case a slip-ring motor with rheostatic control would not be desirable, owing to the constant loss of power in the regulating resistances. Both multi-speed motors and cascade-connected motors can be used here with advantage, though separate motors for the two speeds are sometimes preferred. In the case of rope-driven fans the different speeds can be obtained by changing the driving pulley. Speed reduction of fans is also required for short periods, as, for instance, where a lower air-pressure can be used over the week-end. In this case a slip-ring motor with rheostatic control is often the best system to adopt.

The simplicity of the slip-ring motor with rheostatic control and its low first cost render it preferable to the different complicated systems which are now put forward, showing a high efficiency at all speeds. When the extra first cost, maintenance, and attendance of these systems are balanced against any small saving of power they may show at low speeds, the advantages rapidly vanish. Also, since the slip-ring motor has a higher efficiency than any other system at the top speed, that is over the longest running period, it will in many cases show an even lower power consumption than is shown by other systems.

Starting of Squirrel-cage Motors. — Squirrel-cage motors of small size can be started by switching full voltage on to their terminals. In this case about six times full-load current is taken momentarily, which current is independent of the load

* Abstract of paper read before the Manchester local section of the Institution of Electrical Engineers, January 14th, 1913.

to be started, though its effect on the supply voltage is, of course, more noticeable when starting a heavy load than when starting a light load. The torque developed may be about twice normal torque. All squirrel-cage motors can be started in this way; but above a certain size, say 5 h.p. to 10 h.p., the starting current is usually considered excessive, and an auto-starter or star-delta starter, or in the case of 2-phase motors, a series-parallel starter is used. The auto-starter consists of a transformer and a double-throw switch, by which a reduced voltage is thrown on to the motor terminals at starting, causing a reduced current to be drawn from the line, and a lower torque to be developed.

If different voltages are thrown on to the terminals of a motor, and the current and torque of the motor are measured, it will be found that the current varies directly as the voltage, whereas the torque (neglecting the torque necessary to overcome the bearing friction) varies as the square of the voltage. So that a motor which with full voltage on its terminals gives twice normal torque, and takes six times normal current, will, when 50 per cent. of full voltage is thrown on to its terminals, give half normal torque and take three times normal current. If this is done by means of an auto-starter with a 2 : 1 ratio, then when the current in the motor is three times normal, the current in the line is $1\frac{1}{2}$ times normal, since the k.v.a. on the primary and secondary of the auto-starter are equal. In the same way it is found that with a tapping giving 70 per cent. of full voltage, three times normal current is drawn from the line and full-load starting torque is developed. It will easily be seen from this that the starting torque and line current are dependent upon the ratio of the auto-starter, and that the current drawn from the line at the moment of starting is directly proportional to the torque developed. It should be clearly understood that the maximum value of the starting current of any motor is quite independent of the starting load, and depends entirely on the voltage which is thrown on to the terminals of the motor. With the star-delta starter the motor is designed to run connected in delta. Leads are brought out from both ends of each phase, and by means of a double-throw switch the motor is started in star connection, and when up to speed is switched over to delta connection. By this means rather less than 60 per cent. of full voltage is thrown on to each phase at starting, corresponding to an auto-starter with a 60 per cent. tapping. The series-parallel starter used with 2-phase motors in which the windings are connected in series for starting, and in two parallel circuits for running, is seen in the same way to have the same effect as a 50 per cent. tapping.

It might be imagined that by using a reduced voltage at starting, the total energy absorbed during starting would be reduced. Such, however, is not the case, and the following general theorem for induction motor starting is found to be true: (1) When a squirrel-cage motor starts against a load consisting entirely of inertia, the total energy absorbed and the heating of the motor during starting are independent of the starting voltage. In this the heat dissipated during the starting period is not considered. (2) If the load consists partly of a friction load, the energy absorbed and the heating of the motor are reduced if the starting voltage be increased.

When starting on loads which consist chiefly of friction, such as compressors, tube mills, &c., a high starting voltage is advantageous, whereas for loads consisting chiefly of inertia the value of the starting voltage is not so important. Since, however, there is always a certain friction element in the load, a high starting voltage is preferable where there is no objection to the consequently heavy starting current.

Slip.—Reference was made above to the importance of correctly proportioning the slip of a squirrel-cage induction motor. It is important that the slip be not too great, since a large slip represents a large constant loss when the motor is running on load, and a corresponding reduction in efficiency. The slip must not, however, be made too small, and is actually fixed by considerations of starting torque. The starting torque is directly proportional to the resistance loss in the rotor at the moment of start, and is, therefore, proportional to the resistance of the rotor and to the square of the rotor current. With a given stator winding the starting current does not alter appreciably for small alterations in the rotor resistance, and the starting torque will vary almost in proportion to the rotor resistance.

Determination of Short-circuit Current.—In order to determine the starting torque of an induction motor it is necessary to determine the starting current, or as it is generally known, the "short-circuit current" of the motor. The value of the short-circuit current depends partly upon the resistance, but chiefly upon the magnetic leakage of the motor windings. At starting, the stator and the rotor currents, which oppose one another and are approximately equal, combine to produce a leakage field, in other words a field, every part of which passes through one but not both of these windings. Since in any motor this leakage field is produced by the combined action of the stator and the rotor currents, it is proportional to these currents, and, therefore, to the terminal voltage.

If two motors, exactly similar except for magnetic leakage, be compared, the one having the greater leakage will for the same current have a greater leakage field, and will, therefore, require a higher terminal voltage than the other. Therefore with equal terminal voltages the first motor will have a lower short-circuit current than that of the other motor. The magnetic leakage and the short-circuit current of an induction motor, even that of a completely new type, can be calculated; but such a calculation is extremely difficult. For the determination of the short-circuit current many formulæ have been put forward, some of which give extremely good results. The safest course is to use a fairly simple formula, and to allow a margin of safety until sufficient experience has been gained to permit an accurate estimate of the short-circuit current to be made. The result of over-estimating the short-current is seen from the following example:—

Suppose the motor has been designed with a certain slip at normal load, calculated from the normal current. A certain starting current is expected which would give, say, twice normal starting torque with full voltage. Supposing the actual starting current is 20 per cent. lower, as might easily be the case if the motor was of a type with which the designer was unacquainted, then instead of twice normal torque at starting we should only have 1·3 times. If the motor is started by means of an auto-starter, then, whereas we expect to obtain full-load starting torque with three times full load current, it would actually need nearly four times full-load current to produce this torque at starting. The motor should have been built with a higher rotor resistance and a stronger field.

Motors which have an unusually large short-circuit current can be built with a relatively small slip and still develop a good starting torque, for the slip is decided not only by the starting torque required, but also by the short-circuit current of the motor. Sufficient starting torque can usually be obtained by taking a normal slip of 4 or 5 per cent., though on motors of large size this value of slip can generally be somewhat reduced. High-speed motors especially, for pump driving, requiring a comparatively small starting torque, are generally designed with a normal slip of not more than $2\frac{1}{2}$ to $3\frac{1}{2}$ per cent., giving an increase of efficiency at normal load and a reduced starting torque.

When specially heavy starting torque is required, as for crane motors, and motors for operating sluice valves or small compressors, squirrel-cage motors are built with rotors of much higher resistance, giving a slip of 8 to 10 per cent. at normal load. The rotors are specially built to withstand the heat developed in them without deterioration, and the motors are generally started by switching full voltage on to their terminals, or in the case of crane motors are controlled by varying the terminal voltage, by means of an auto-transformer provided with different voltage tappings.

Heating of Motor during Starting Period.—The heating of a motor is dependent upon the starting voltage, and in order to give an idea of what this heating may amount to, the following example is given of the starting of a squirrel-cage motor which drives by a belt a heavy mining fan. These fans, owing to their great inertia, are well known to impose very severe starting conditions upon squirrel-cage motors. The fan delivers 100,000 cub. ft. of air per minute against $4\frac{1}{2}$ w.g. Its runner has a weight of 1 ton and a radius of gyration of 3ft., and its speed is 415 revs. per minute. The motor is of 100 h.p., 3-phase, 50 cycle, 500 volts, 720 revs. per minute, and starts on a 70 per cent. voltage tapping. It has a starting torque with the rotor cold of 1·75 × normal

with full voltage, and a normal slip of 4 per cent. The load is assumed to consist of a constant friction-load of 150lbs. torque at 1ft. radius at different speeds, the remainder increasing with the cube of the speed, giving together an ultimate value of 730lbs. at 1ft. radius at full speed. In addition to this we have to allow for accelerating the mass of the fan, which when reduced to the motor speed is equivalent to 3 tons at 1ft. radius.

As is well known, the rotor is heated up during starting far more than the stator. This is partly due to the fact that the heat produced in the rotor is greater, owing to the resistance being necessarily higher, for obtaining sufficient starting torque. It is also due to the fact that the rotor winding is more concentrated than that of the stator, so that for equal resistances its heat capacity would be lower than that of the stator winding. No attempt has been made to determine the heating of the stator during starting, since experience proves that the stator does not heat up to any extent during the starting period. The rate of heating of the rotor at any instant during the starting period, by which the heating curve of the rotor is determined, depends upon the current in the rotor and the resistance and heat capacity of the rotor windings at that instant; also upon the amount of heat dissipated by the rotor, which is proportional to the temperature rise of the windings at that instant, and is also a function of the speed.

When the motor was first started, the rotor heated up so rapidly that though the current was diminishing the rate of heating increased, owing to the fact that the resistance of the rotor was increasing. After 30 seconds, when the motor was nearly up to speed, the rotor still had a temperature rise of 95° C., corresponding to an increase in slip of nearly 40 per cent. above its slip when cold. On switching over to full voltage the motor came up to a speed of 712 revs. per minute, and gradually crept up to its normal speed of 720 revs. per minute as the rotor cooled off. The rotor had a maximum temperature rise of 126° C., meaning an actual temperature of perhaps 150° C. This may appear excessive, especially when thinking of temperature rises of the order of 40° C. for motors. Such, however, is not the case, since a rotor of good design and construction can stand temperatures far in excess of this without deterioration. When running at normal load the rotor had a temperature rise of less than 20° C., and the heating which occurred during starting was entirely local, since there was not sufficient time for heat to be transmitted to the stator.

Though the temperature of 150° C. is not sufficient to melt solder, it would certainly be undesirable to use solder on a rotor which operates under such severe conditions. Any screwed or riveted contacts would be liable to deteriorate under such conditions, even if the design and workmanship were very carefully carried out, and the only thoroughly satisfactory design is one in which all the contacts are brazed or welded. In some experiments made on different contacts some years ago, it was found that the voltage drop on a tightly screwed or riveted contact was so small when the contact surfaces were clean that it was indistinguishable from the solid metal, even when the surfaces in contact were very small. However, even with machined and accurately fitting surfaces, on alternately heating the test pieces to temperatures of 200° C. and allowing them to cool, the contact drop was found to increase very rapidly.

In addition to heating, vibration is found to have a very bad effect on squirrel-cage rotors, and cases have been known where, through one or other of these causes, the rotor has deteriorated to such an extent as to be practically open circuited; in other words, the motor would not even run. In the early history of the induction motor, when motors were of a large size and of ample heat capacity, there was very little trouble of this nature. Of course thousands of induction motors are in operation to-day with soldered rotors or with riveted or screwed joints. Many of them give no trouble, particularly when the starting conditions are easy. Many others give trouble, due either to vibration or to overheating, which trouble may not be suspected at first, and perhaps not until the consequent overheating has necessitated rewinding the stator as well as the rotor. There is no doubt that the rotor is the weakest part of a modern squirrel-cage motor, if screwed, riveted, or sweated, for which reason on a motor of good design all the contacts should be brazed or welded, by which method of construction most of the troubles experienced on these motors are eliminated.

CONCLUSIONS.

For constant speed work the squirrel-cage motor is greatly to be preferred to the slip-ring motor, and can be used where its starting current is not objectionable.

For motors of very large size the slip-ring type is generally preferred.

For variable-speed work the slip-ring motor is generally used. The squirrel-cage motor can be used for intermittent service, but only in small sizes, or when the use of slip-rings is not desirable.

When the speed is reduced continuously on heavy torque, the slip-ring motor is not suitable, owing to the constant rheostatic losses, and a multi-speed motor giving several efficient speeds is preferred.

The multi-speed motor is also used where good speed regulation is required at several speeds.

Where the torque at reduced speeds is diminished, the slip-ring motor with rheostatic control is often the best system.

For fan-driving, where the speed is occasionally reduced, the average power consumption with the slip-ring motor may be as low as or even lower than with other systems, as well as the first cost being lower.

Starting of Squirrel-cage Motors.—When starting a motor with an auto-starter, if the maximum current and the maximum torque at starting are measured at different voltages, the current drawn from the line is seen to be directly proportional to the torque developed.

If the motor starts against a load consisting entirely of inertia, the total energy absorbed and the heating of the motor are independent of the starting voltage.

If the load consists partly of a friction load, the energy absorbed and the heating are reduced if the voltage be increased. From which it is seen that a high starting voltage is generally advantageous.

When the starting conditions are fixed, and the friction of the load is fixed but the inertia is varied, then the time of starting, the total energy absorbed and the heating of the motor are proportional to the inertia of the load.

Slip and Short-circuit Current.—The determination of the short-circuit current and the correct proportioning of the "slip" are of very great importance in the design of a squirrel-cage motor. The starting torque is dependent upon the short-circuit current, and upon the slip at normal load. The slip at normal load is not, therefore, a definite percentage, but depends upon the required starting conditions. In the same way a motor with an inherently large short-circuit current can be built with a small slip.

Heating of Rotor during Starting. — The starting of a load of great inertia imposes very severe conditions upon the rotor of a squirrel-cage machine. Squirrel-cage rotors with screwed, riveted, or soldered joints are always liable to give trouble owing to overheating during starting, or to vibration when running. The trouble can be completely overcome by brazing or welding all joints, so that the rotor, which is otherwise the weakest part of the machine, becomes practically indestructible.

Association of Mining Electrical Engineers.—The Council of the Association announces that the following prizes are offered for papers for the present session: An Association prize of five guineas for the best paper read at any branch. A prize of two guineas, given by Mr. Carlow, for the best paper by a member of East Scotland branch. A prize of four guineas, given by Mr. Alex. Anderson and Mr. Matthew Brown, for the best paper by a working colliery electrician who is a member of the West of Scotland branch. A premium of two guineas, given by Lord Joicey, for the best paper by a member of the North of England branch. As in previous years, examinations for competency in mining electrical engineering will be held on Saturdays, March 8 and 15, 1913, in ten different centres in the United Kingdom, full particulars relating to which can be obtained from the general secretary of the Association, Bank Chambers, Derby, or from any branch secretary.

FATAL EXPLOSION IN AN OIL-FIRED MARINE BOILER.

THE inquest on the five victims of the accident which took place on board the new oil ship "San Eduardo" while lying at the Neptune yard of Messrs. Swan, Hunter, & Wigham Richardson, Ltd., Walker, on December 26th last was concluded at Newcastle on the 19th inst. The accident occurred in the stokehold, a sheet of flame suddenly flashing out of one of the furnaces, which were oil fired, overwhelming nine of the men, five of them so seriously that they subsequently died.

Mr. A. T. Thorne, an engineer employed by Messrs. Swan, Hunter, & Wigham Richardson, described the condition of the stokehold immediately after the accident. There were evidences of a fire having occurred, but nothing was greatly disturbed. The three boilers were all heated with oil fuel, and in the port aft boiler the fires were out. The fires in the other boilers were burning feebly, and he thought something was the matter. There was staging in front of the boiler, and it was obvious that the men had been engaged cleaning tubes. Mr. Joseph Swan, foreman boilermaker at the Neptune Engine Works, said he was in the stokehold of the "San Eduardo" on the morning of December 26th. Shortly after nine o'clock he noticed dense smoke, and almost immediately there was a flash and an explosion. He did not observe where it originated, for he was thrown to the ground.

J. J. Robinson, a fitter, said he had been working on the "San Eduardo" for some days prior to December 26th. He had seen that the damper in the funnel was in an open position, and to make doubly sure he lashed the lever with wire. He went on board the vessel on Christmas night, and remained until eight o'clock next morning. There had been an official test of the engines and boilers in the presence of Lloyd's and the owner's representatives, and everything had passed off satisfactorily. Between four and five o'clock on the morning of December 26th, he drew retarders from each of the tubes of the forward and starboard boilers, and then lit the fires of those two boilers. He drew the retarders to give more "vent" to the flame. Prior to lighting the fires he examined the lever of the damper and saw that it was lashed as he had left it. The furnaces burned brightly. Witness left the ship, and subsequently was sent for on account of the accident. He saw Mr. Dickinson, who said the lever of the damper had been released, and that the damper had been found closed. Naphtha lamps were not used during the time he was in the stokehold. He considered there was sufficient ventilation.

W. Dickinson, foreman engineer, said it was part of his duty on Boxing Day to see that steam was got up on the main boilers of the "San Eduardo." He gave orders for 100lbs. to 120lbs. pressure to be up by nine o'clock. Shortly after eight o'clock he noticed that the lever of the damper was lashed in an open position, and the damper could only be closed if the lashings were removed, and the lever drawn down and pinned. At nine o'clock witness told one of the deceased men that there was to be a test of the steam-heating pipes in the hold, and that he was to see that steam was up. Witness then went on shore, and on returning to the ship found the stokehold filled with dense black smoke. He opened the smokebox and then found the damper was closed. The lever was pinned down, shut. He had been unable to find who had released the lever. Asked for his theory as to the cause of the accident, witness said the damper being closed would cause gases to accumulate, but he did not know how they became ignited. He did not think the damper could have been closed when the fires were lighted, or the man who lit the fires would have noticed it.

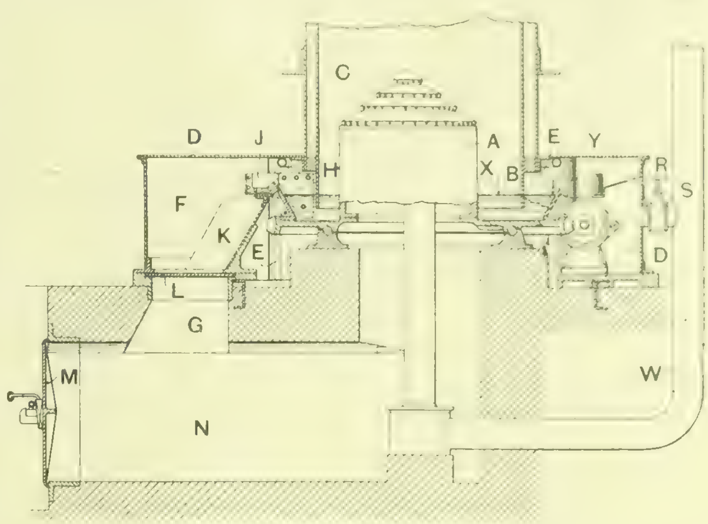
Mr. F. Piercy, assistant manager of the Wallsend Slipway Company, gave expert evidence as to the oil fuel. He said the fuel fittings on the "San Eduardo" were made by his firm, but they did not do any fixing. Referring to the damper in the main funnel, he said the fact that the lever was lashed was recognised as an intimation that the lever must not be touched. The fuel used in the "San Eduardo" had a high flash point. It gave off vapour, which would burn when mixed with air only if heated to 202 Fah. The oil in bulk would not ignite at that point. He was of opinion that, when the damper was closed, there was a sufficient amount of air uncombined to continue combustion in the furnace for a short while. Combustion would, therefore, proceed, and the products of combustion, owing to the increased temperature, would want to expand. They must find an outlet and they got out through the furnace doors, hence the long flame in the stokehold. He was of opinion that the damper must have been in an open position until immediately before the accident. He had never heard of a similar accident having occurred. The only reason he could give for the accident was the damper being closed.

Mr. G. Vardy, manager of the Neptune Engine Works, said, after learning of the accident he went to the stokehold of the vessel, where he found indications of a recent fire. All the fires were out, and, with a view to discovering the cause of the accident he gave instructions for the smokebox on the furnace, where the men had been working, to be opened. He found the damper had been shut. That would cause the accident. He could form no other opinion. He thought that the damper was closed very shortly before the accident happened. If it had not been the smoke would not have come from the smokebox. He did not think it necessary to have dampers at all when burning oil.

The jury returned the following verdict: "The cause of the accident was the closing of the main damper while the furnace of two of the boilers of the ship were burning and the smokebox of the third boiler was open, but by whom, or for what purpose the damper was closed, there was no evidence to show. Death was directly due to the accident."

ROTARY GRATE FOR GAS PRODUCERS.

IN the usual arrangement of rotary grates as fitted to gas producers of the Kerpely type, it is only possible to keep the rotary pan filled with water if the level of the water in the pan when filled is below the lower end of the shell of the generator. If the water level rises above this point the pres-



ROTARY GRATE FOR GAS PRODUCERS.

sure inside the generator forces the water over the edge of the pan till the former level is attained. In order to obviate the drawbacks attendant upon this intermittent overflowing of the water, it is necessary to maintain the same pressure in the surrounding air-tight annular chamber as in the generator shaft. This result is obtained in the arrangement illustrated, which has recently been patented by Mr. A. Von Kerpely, Kaiser Wilhelmsring 16, Vienna, by placing the chamber in communication with the blast supply at any suitable point. Where this is done the pressures on the surface of the water within and without the shell of the generator are equal, and neither a forcible discharge of the water nor an overflow of same over the edge of the pan can take place. Referring to the illustration, A is the rotary grate, B the rotary pan, C the stationary generator shaft, D the sheet iron casing externally enclosing the air-tight chamber E. The blast supply pipe W is placed in communication with the chamber E through a branch R which is adapted to be closed by a full way valve S. As a result of the arrangement the same pressure prevails in the chamber E at Y as in the shaft C at X, thereby preventing the overflow of the water. Closing the valve S enables the former conditions to be restored. The arrangement is particularly suitable when dealing with fuels yielding a readily fusible ash or the working of which is attended with the generation of more than ordinary heat.

CIRCULATION OF WATER IN LOCOMOTIVE BOILERS.

An exhaustive report by Prof. W. F. M. Goss, on the comparative test of the Jacobs-Shupert and radial stay types of locomotive boilers, has recently been issued by The Jacobs-Shupert United States Firebox Company, of Coatesville, Penn., U.S.A. The report is supplemented by one prepared by Mr. George L. Fowler, giving the results of his investigations conducted for the purpose of determining the facts relating to the circulation of water in locomotive boilers.

The motion of the water within a locomotive boiler in response to the energy transmitted to it in the form of heat

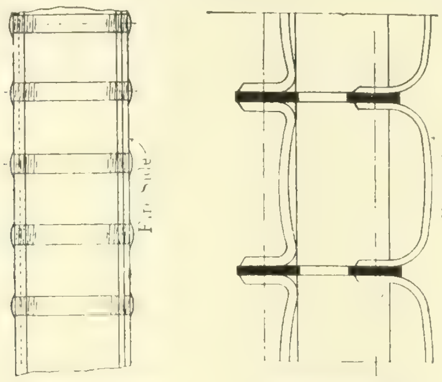


FIG. 1.—HORIZONTAL SECTIONS OF WATER-LEGS, RADIAL-STAY, AND JACOBS-SHUPERT FIREBOXES.

is known to have an important bearing on the upkeep and life of the boiler, and there has been much speculation concerning the direction and strength of the circulation currents. It has been urged, for example, that the presence of the stay-sheets which enter into the construction of the Jacobs-Shupert boiler retard the fore-and-aft movement of water, and that they are, therefore, objectionable. As the stay-sheets are provided with widely distributed openings of large area, such criticisms necessarily assume fore-and-aft currents which are tremendously vigorous. The presence of such vigorous currents has been questioned. An experimental enquiry conducted by Mr. George L. Fowler sustains the very rational contention that only enough water passes back from the barrel of the boiler to the water-legs of the firebox to make good that which the firebox evaporates. Since the firebox

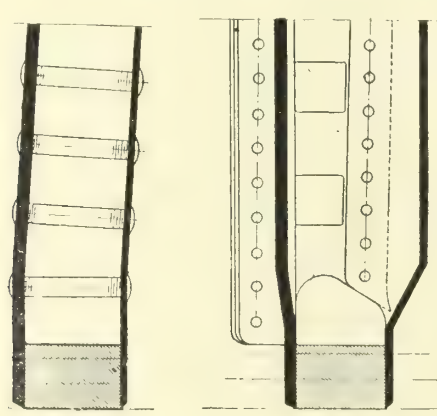


FIG. 2.—VERTICAL SECTIONS OF WATER-LEGS, RADIAL-STAY AND JACOBS-SHUPERT FIREBOXES.

evaporates from 30 to 50 per cent. of the water handled by the boiler, a similar percentage of the total feed must, in the case of the Jacobs-Shupert boiler, find its way through the ports in the forward stay-sheet. Some of this water is evaporated before the second stay-sheet is reached. With the passage of each section, the backward flow diminishes until at the last stay-sheet only enough passes to supply that which the last section evaporates. Obviously an aggregate port area of 1⅗ sq. ft. is quite sufficient to pass from 30 to 50 per cent. of the water which the injector delivers through a 2in. or a 2½in. pipe. The text of Mr. Fowler's report is substantially as follows:—

The apparatus used for the purpose of determining the facts with reference to the circulation of water in the Jacobs-Shupert and the radial-stay boilers under test was designed to measure the velocity and direction of flow as well as the quality of the mass of the liquid at different points of the water-leg of the firebox, and is shown diagrammatically in Fig. 4. The principle of its operation is that of measuring the impact of the flow of the mass in the water-leg upon the mouth of a Pitot tube, by means of the elevation of a liquid heavier than water in a U-tube, and afterward determining the quality of the liquid, that is, the proportions of contained water and steam by means of samples led off into a barrel calorimeter. The Pitot tubes were inserted in the firebox at the points where it was desired to make the measurements, and could be moved to and fro through suitable stuffing-boxes so that the opening could be placed at any point between the two sheets. At the same time it was revolvable so as to be turned to face in any direction. The construction of the apparatus in detail was as follows:—

The Pitot tube G (Fig. 4) was inserted in the water-leg and was connected by means of the flexible pipe C with the top of a water-glass F. From the bottom of the water-glass F another flexible tube B ran to the bottom of the water-glass E; while from the top of the water-glass E, a third flexible tube A ran to a point in the firebox below the water-line. The flexible tube B and the two water-glasses formed a U-tube which was filled to the centre of the glasses with tetrachloride of carbon that was coloured red and whose specific gravity is exactly 1·6. It was evident that,

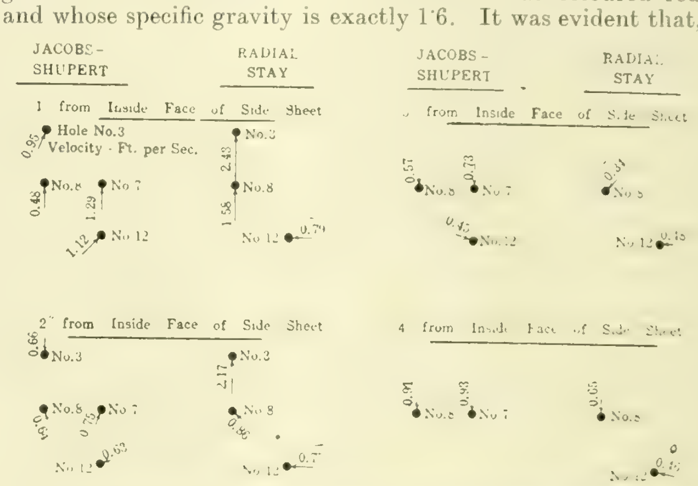


FIG. 3.—DIAGRAM SHOWING VELOCITY OF MIXTURE OF STEAM AND WATER IN FEET PER SECOND IN DIFFERENT PORTIONS OF WATER-LEG.

with connections to the boiler as shown, the liquid will stand at the same height in each of the two glasses so long as the pressure above the tetrachloride of carbon in each leg remains the same, but if the pressure on either leg exceeds that of the other, the tetrachloride in the leg of the higher pressure will be correspondingly depressed. This increase of pressure was secured by turning the Pitot tube, and when it faced directly into the stream, it would produce the greatest pressure at the top of the glass F, with a corresponding depression of the tetrachloride in that leg.

For convenience of entering the boiler 15 holes were drilled in the side of the firebox. They were in three rows, five in a row and numbered, for the sake of identification, as shown in the accompanying diagram, Fig. 5. After a reading had been taken the valve H was closed and the valve I was opened. This cut the pressure off from the top of the water-glass F, and allowed the mixture of steam and water entering the Pitot tube to flow into the water partially filling the barrel calorimeter K, when from the temperature ranges before and after the admission of the liquid from the boiler, together with the pressure existing at the time as read from the steam gauge, it was possible to determine the percentage of steam and water entering into the mixture as it existed at the mouth of the Pitot tube in the water-leg. From this information the specific gravity of the mass could be calculated. Then with the head produced by the difference in the levels of the tetrachloride of carbon and the specific gravity of the liquid whose impact caused that difference of level, the velocity of the liquid can be calculated. This is the method followed in all of the observations which are recorded in Tables I. and II.

The heat (B.Th.U.) given is for that above 32 Fah. The column headed "angle of flow," indicates the observed angle at which the mass was moving at the time of the observation. It is measured in the direction of the movement of the hands of a watch, starting with 0 for the vertical downward movement. Then 90° would be horizontally from the front to the back; 180° vertically upward, and 270° horizontally from the rear to the front. The "specific gravity of the mass" denotes the specific gravity of the combined mass of steam and water. The "velocity of the mass" is the velocity which a mass of the corresponding specific gravity would have to have in order, by its impact on the mouth of the Pitot tube, to cause the difference in the level of the tetrachloride as observed. The "velocity of the steam," given in the last column, is the velocity that steam of the pressure existing in the boiler at the time of the observation would have to have in order to cause the observed difference in the levels of the tetrachloride.

movement from front to back, broken throughout the whole course by violent agitation, and innumerable cross currents, but that in no place are these currents torrential nor is the steam movement itself very rapid, while in some places there is a true circulation, that is, the water follows a definite path, returning to a previous position. An example of this is found in the tests at hole 8 of the radial-stay boiler on June 4th. At 1in. from the inside sheet there was an upward flow of 1·71ft. per second; at 2in. the flow was still nearly vertical; at 3in. there was a neutral point at which no movement could be detected; while at 4in., or near the outer sheet, there was a vertical movement downward. The same thing is observable with the Jacobs-Shupert firebox at holes 7 and 8, but without the indication of a neutral zone devoid of flow.

There are some peculiarities in the observations that cannot be accounted for because of the limited data. For example, in the observation at hole 12 of the radial-stay boiler, the

TABLE I.—*Tests on Radial-stay Boiler.*

Date	Time	No. of Hole	Distance from Inside Sheet, Inches	Height of Liquid in U-tube, Inches	Water: Weight Lbs	Water: Temp Fahr	Calorimeter: Weight Lbs	Calorimeter: Temp Fahr	From Boiler: Weight of Water Lbs	From Boiler: Total B.T.U.	From Boiler: B.T.U. per Lb Water	Angle of Flow	Boiler Pressure Lbs	Percentage of Steam in Mass	Specific Gravity of Mass	Velocity of Mass in Ft per Second	Velocity of Steam in Ft per Second
June 3	A.M.	8	1	1	400 5	78	440 0	114	39 5	19,478	493	180	200	15 7	850	1 92	20 65
"	"	8	2	1/8	431 5	82	460 0	106	29 5	13,940	472	147	220	12 4	895	.67	7.00
"	"	12	1	1/4	404 0	82	448 0	112½	44 0	18,064	411	90	190	6 4	928	93	10 49
"	"	12	2½	1/8	416 0	83	454 0	114	38 0	17,950	473	90	185	14 0	847	69	7 51
"	"	8	3½	1/8	394 5	84½	445 0	129	50 5	25,105	497	55	220	15 5	873	68	7 00
"	2 54 P.M.	8	1	3/8	332 0	86	376 5	110	44 5	13,842	405	180	180	6 0	.980	1 10	13 17
"	3 26 "	8	2	3/8	316 5	88	356 0	118	39 5	15,104	382	152	170	3 7	967	1 11	13 50
June 4	9 13 A.M.	8	1	7/8	358 0	78	386 5	100½	28 5	11,418	400	180	205	4 5	954	1 71	19 00
"	10 33 "	12	1	1/8	376 0	83	416 5	112½	40 5	16,418	405	90	205	5 1	.949	65	7 19
"	11 00 "	12	2	3/32	341 0	86	396 0	128	55 0	22,572	410	90	205	5 7	943	.80	8 79
"	11 20 "	12	3	1/16	348 0	88	400 0	128½	52 0	22,024	435	90	210	8 4	921	48	5 02
"	11 44 "	12	4	1/16	336 0	88	388 0	128½	52 0	21,538	414	93	210	5 9	.943	46	5 02
"	1 30 P.M.	8	2	3/16	339 5	86	388 0	123	48 5	19,594	404	175	220	4 3	980	.79	11 12
"	1 54 "	8	3	0	342 0	88	386 0	122½	44 0	18,245	415	. .	215	5 8	.947	00	0 00
"	2 12 "	8	4	1/8	341 5	88	383 5	122	42 0	17,743	422	0	205	7 1	930	65	10 00
June 5	8 45 A.M.	3	1	1½-2	318 0	76	350 0	106	32 0	13,316	416	180	215	6 0	944	2 25 / 2 60	24 35 / 28 12
"	9 41 "	3	2	1¼-1½	320 0	82	347 5	104	27 5	10,375	377	180	155	4 2	935	2 07 / 2 26	25 67 / 25 1[illegible]

TABLE II.—*Tests on Jacobs-Shupert Boiler.*

Date	Time	No. of Hole	Distance from Inside Sheet, Inches	Height of Liquid in U-tube, Inches	Water: Weight Lbs	Water: Temp. Fahr.	Calorimeter: Weight Lbs.	Calorimeter: Temp Fahr	From Boiler: Weight of Water Lbs	From Boiler: Total B.T.U.	From Boiler: B.T.U. per Lb Water	Angle of Flow	Boiler Pressure Lbs	Percentage of Steam in Mass	Specific Gravity of Mass	Velocity of Mass in Ft per Second	Velocity of Steam in Ft per Second
June 7	3.50 P.M.	8	1	1/4	331 0	77	373 0	110	42 0	18,926	451	180	170	12 8	843	48	11 02
"	4 15 "	8	2	1/8	299 0	84	328 0	108½	29 0	11,032	380	160	205	2 1	976	64	7.18
"	4.30 "	8	3	3/32	328 0	76	364 5	108	36 5	14,876	408	0	202	5 8	940	57	5 05
"	4 40 "	8	4	1/4	359 5	77½	402 0	109	42 5	16,530	389	0	210	2 5	975	91	10 09
"	5.10 "	12	1	3/8	344 0	81	381 5	112	37 5	15,501	413	225	225	5 2	954	1 12	11 94
"	5.30 "	12	2	1/8	343 5	78	398 0	115	54 5	19,760	363	75	125	4 4	912	63	8 93
"	5 45 "	12	3	1/16	322 5	84	370 0	123	47 5	19,370	408	315	225	4 5	961	45	4 87
June 8	10.45 A.M.	7	1	1/2	344 0	65	406 0	116	62 0	24,898	401	180	220	3 9	964	1 29	13 82
"	11 05 "	7	2	3/16	350 0	84	395 0	118½	45 0	18,307	418	190	220	5.9	947	79	8 53
"	11 23 "	7	3	3/32	349 5	89	386 0	116	36 5	14,583	400	0	215	4.0	962	.73	7 87
"	12 00 "	7	4	1/4	338 5	86½	381 5	120	43 0	17,467	406	0	200	4.5	952	93	14 60
"	12 22 "	3	1	1/4	352 0	85	384 5	113	32 5	14,211	437	190	190	9 5	897	95	14 85
"	12.45 "	3	2	1/8	344 5	94	374 5	118	30 0	12,708	423	0	190	7.8	913	66	10 89
"	.	7	4	3/16	. . . .	. .	. .	.		. . .		0		. .		.	. . . .

These velocities are calculated on the basis of the elevation of a mass whose specific gravity is 0·6, for this reason. The specific gravity of the tetrachloride is 1·6. The 1 is balanced by the superincumbent weight of water in each leg of the U-tube, leaving only the ·6 to be moved by the impact on the Pitot tube.

In handling the apparatus and making the observations here recorded, the difference in level of the tetrachloride was first observed. Then water and steam were blown through the piping, leading to the calorimeter sufficient to heat it, after which it was turned into the barrel for the measurement of its heat values.

The records of the angles of flow must not be taken as positive and fixed. The figures given are for the approximate average inclination of the flow. As a matter of fact it shows every evidence of constant variation, sometimes through angles approximately 45° for the higher velocities, and this together with other general indications have led to the opinion that there is much agitation in a boiler, with comparatively little circulation of progressive movement of the water. It is thought that if the matter were to be examined to a finality it would be found that there is a regular slow

three records of the third show a constantly increasing percentage of steam in the mixture from the inner sheet to the outer. This is checked by the observations on the fourth, except that the one at 4in. from the sheet, which is farther out than that of the third, shows a falling off as the outer sheet is approached. This same condition, though not so markedly, appears in the Jacobs-Shupert boiler at hole 7. As for the general character of the water movement, there is, in the radial-stay boiler an entire absence, so far as observations went, of eddy or reverse currents. The movement is either vertical or back from front to rear, whereas in the Jacobs-Shupert firebox, with the general movement the same, there was one hole where the movement was from the rear to the front, evidently due to eddies set up by the stay-plates. In calculating these velocities corresponding to the heights, it has been assumed that these heights or differences of level vary as the impinging mass and that the squares of their velocities vary inversely as the mass.

It is to be observed that the percentages of steam are less in the Jacobs-Shupert than in the radial-stay boiler. From the data of the tests it is possible to determine the probable rates of evaporation in the radial-stay boiler, while from corre-

sponding tests with the Jacobs-Shupert boiler,* the evaporation is estimated to have been about 12lbs. per square foot of heating surface per hour. And the boiler was being fed with water at a temperature of about 70° Fah. The rate of movement, too, was more rapid with the radial-stay than with the Jacobs-Shupert, but in both cases the movement was so slow that no criticism can be offered as to the checking of the flow by the stay-plates of the Jacobs-Shupert firebox. Evidently, from the rate of flow and the percentage of steam

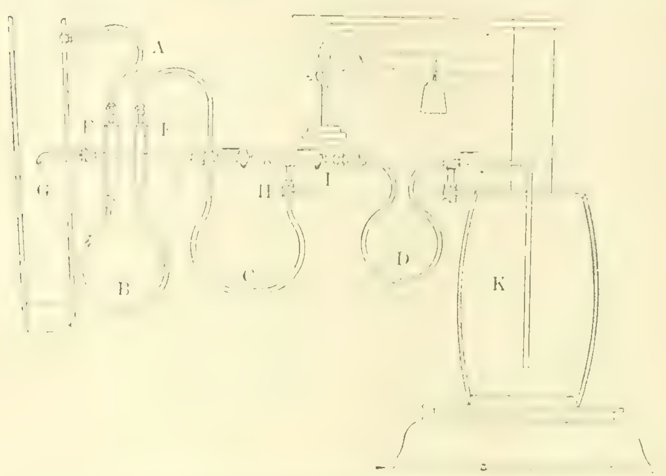


FIG. 1.—APPARATUS FOR DETECTING CIRCULATION OF WATER IN BOILERS.

contained in the water, there was ample opportunity for the water to come back and completely fill the leg.

Incidental to this, it was observed that a change in the rate of steam flow through the exhausting pipes would have its effect on the velocity of the currents in the water-leg of the firebox. The opening of the safety-valve, for example, would increase the speed at once, while when the pressure was being raised, the water seemed quite stagnant.

In order to ascertain the likelihood of there being a straight flow of cold water from the front to the rear over the top of the foundation ring, a thermometer was placed at the back lower corner of the Jacobs-Shupert firebox on the eighth, when being driven as already indicated and using feed water at a temperature of about 70° Fah. When the boiler was at work under 215lbs. pressure the observed temperature at this point was 380° Fah., or only 13° below the boiling point at that pressure, this indicating either a circulation through hot portions of the boiler before reaching the back

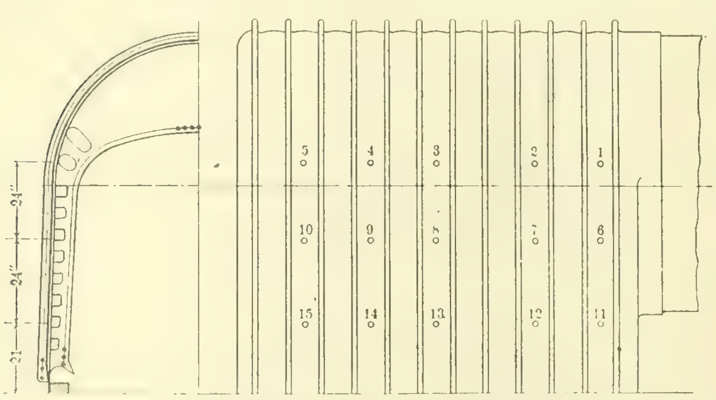


FIG. 5.—LOCATION OF HOLES FOR CIRCULATION TESTS.

end of the water-leg, or an agitation of the water en route and its mingling with quantities of steam or hot water, by which its temperature was raised.

While the tests cannot be regarded as conclusive, they indicate that neither the water nor steam velocities of a locomotive firebox are high, and that the opening in the stay-plates of the Jacobs-Shupert firebox are quite sufficient to admit the water in ample quantities to all parts of the water-leg. Finally, it is desired to suggest that many of the seeming inconsistencies of these observations may be attributed to the interval of time between them. This varied from 15 minutes to 45 minutes, during which periods there was ample time and opportunity for such changes to occur in direction of flow and rate of evaporation as to fully account for the actual changes observed.

* The circulation tests on the radial-stay boiler were made in the laboratory during the evaporation tests on that boiler, while the circulation tests on the Jacobs-Shupert boiler did not occur until after the boiler had been transferred to the low water testing grounds, where the conditions of the evaporation tests were duplicated as nearly as possible for the benefit of the circulation tests.

CHEMISTRY APPLIED TO COAL MINING.

At a recent meeting of the Liverpool Section of the Society of Chemical Industry, Dr. John Harger delivered a lecture on "Chemistry applied to Coal Mining." Referring to the composition of the firedamps in mines, the method of analysis adopted by the Home Office, he said, assumed that the inflammable part of firedamp consisted of nothing but methane. If any other combustible gas were present the analyses were incorrect. He then showed that not only was the firedamp in many mines not pure methane, but that gas coming from old wastes very often contained very large quantities of hydrocarbons, heavier than methane. In some experiments with gases sucked from coal by a vacuum, hydrocarbons four times as heavy as methane had been found. It was remarked that, considering the lack of experience of the Home Office staff in such matters, it would have been a prudent course to employ someone with a knowledge of fundamental chemistry instead of relying upon amateurs. The lecturer proceeded to describe a method of determining the actual volume of inflammable gas in a mine air sample, which he had recently worked out. After estimating the carbon dioxide and oxygen, the inflammable gas was combusted by a small quantity of copper oxide on a platinum wire spiral, heated by electric current in the usual way, the contraction (if any) noted, and the carbon dioxide absorbed.

Recalling the method for preventing explosions in mines brought forward in a previous lecture, he stated that he had since been able to work out on a large scale the manufacture of inert gas by using the exhaust from a gas engine. By keeping the gas hot, and in contact with broken firebrick for a short time, every trace of carbon monoxide had been burnt out, even when as little as 1 per cent. oxygen was left. A gas engine exhaust was very hot (1,100° Fah.), and to burn up traces of carbon monoxide in flue gases from gas and coal dust fired boilers, it was necessary to use a strong calalytic agent, and after much experimenting he had discovered that dog iron ore (oxide of iron) would combust carbon monoxide at 400° Fah., and slowly at even less, and if copper oxide were used as well, or instead, the combustion went at 212° Fah. quite well, but a higher temperature was desirable when obtainable. Some criticism had been directed to the possibly injurious effect of a reduced oxygen percentage in mine air on the health of the miners, but all the physiologists who had given their judgment said it would have no harmful effect. Concluding, the lecturer referred to the action of some incombustible substances in causing the combustion of inflammable gas and air at comparatively low temperatures, and pointed out that this did not fit in with the experiments lately made by Prof. Dixon.

Electrical Coal Cutters.—At the monthly meeting of the West of Scotland Branch of the Association of Mining Electrical Engineers, held on Saturday last at Glasgow, Mr. James M'Cann read a paper on "The Electrical Coal Cutter; its Installation and Manipulation." At the outset the author said that when contemplating the installation of a coal cutter at a colliery the first thing to consider was what would be gained. While he held strongly to the opinion that safety should not give place to economy, he also maintained that a clear case for the latter must be made before introducing a coal cutter. It was useless to enter into this phase of the question, because the conditions as a rule differed so much; but there were two points that might be mentioned which would reduce the saving to be gained by the use of coal cutters. These were: (1) That a very bad roof made cutting dangerous and expensive, sometimes impossible; and (2) the saving must be small where the coal was easily won by hand. In such a case, indeed, it would be better practice to introduce a conveyer if the other conditions were suitable. Thereafter the author proceeded to deal with the systems of supply, transmission, and distribution, and the manipulation necessary for the bar, chain, and disc types of machines.

MODERN METHODS OF ELECTRIC WIRING.*

BY FRANK BROADBENT.

THE bases of all wiring and distribution systems are: (*a*) The simple series or constant-current system; and (*b*) the simple parallel or constant-pressure system.

The series system, employed originally with series-wound constant-current dynamos, in connection with lighting by means of arc lamps, preceded the parallel system, and, even after the introduction of the latter, it continued to be used for arc lighting for many years. Although now practically obsolete in this country as a system, the series method of connection is commonly and necessarily used for arc lighting circuits, these circuits being connected in parallel to the mains of a constant-pressure system.

While it is both practicable and convenient to run arc lamps in series, it has hitherto been found impracticable to run incandescent lamps in this way for ordinary indoor lighting purposes. For outdoor lighting, ingenious devices for running incandescent lamps in series have, from time to time, been devised, but these have never got beyond the experimental stage.

For interior wiring, the distribution system is now practically universal in this country. In the simplest form of this system a small installation would have one distribution box, containing a pair of fuses for each lamp. The box would be supplied with current through a pair of main cables, and from each pair of fuses conductors would be led to the individual lamps, switches being connected in, say, the positives or leads. Such a simple system is shown in Fig. 1. This method of running a pair of conductors from a distribution box to each individual light is very rarely used. On motor installations in factories and workshops, this method is undoubtedly the best, as it facilitates testing; it also causes the least possible derangement in the event of any motor being overloaded or faulty. For large installations, several such distribution boxes would be used, each box being fed through a pair of cables or feeders from a main switchboard or distribution box, as shown in Fig. 2.

A large lighting installation, on the distribution system, may be considered as a number of self-contained smaller installations fed from a common source. The installation is divided up into a convenient number of sections, these sections, in some cases, being determined by the number of lights which it is considered desirable should be dependent upon one pair of mains or controlled by one pair of fuses; in other cases, the character of the premises to be lighted largely determines the method of sub-division. Thus, in factories or business establishments which are departmentalised, each principal department might conveniently form one unit or distributing group; in public buildings each floor, or each wing of each floor, might be the most suitable unit in the distributing system, and so on.

In very large installations, such as in large blocks of offices, public institutions, including asylums, infirmaries, &c., a sub-division scheme is necessary. This is the distribution system carried a stage further, and the general features would be somewhat on the following lines. A main switchboard would be located in a power house, or, if supplied from public mains, in a position convenient for distribution, say, in the administrative block of the buildings. From this central point feeders would be run to main distribution boxes located in the various blocks of buildings, or, if the buildings comprise only one block, the various floors. From some, or each, of these main distribution boxes, distributing mains or distributers would be run to sub-distribution boxes, from which circuit mains might be run to smaller sub-boxes. From the final sub-distribution boxes, branches are run to the various groups of lamps. In planning an installation it will often be found that the best plan is to work back from the lighting outlets to the main switchboard, rather than from the main switchboard to the lights. This may at first sight seem to be an incorrect method, but in the long run it may save time. In working forward from the switchboard there is a tendency to fix the positions of distribution boxes in what might be called the geographical centres of the distributing areas; but these centres are not always the centres of gravity—if such an expression may be used—of the outlets. Having decided upon the groups of lights to be controlled by the sub-circuit fuses, and indicated them on the plan, either by numbers or by a line drawn round the lighting points, it will not be a difficult matter to fix on suitable positions for the sub-distribution boxes.

Just as 500 watts may form a safe or convenient limit for the sub-circuits, so also the principal circuits may with advantage be limited to, say, 5,000 watts, corresponding to 50 amperes at 100 volts, or 25 amperes at 200 volts. This practically fixes the number of fuse-ways in the sub-distribution boxes at about 10 or 12. The main distribution boxes should not, as a rule, control so many circuits as are controlled by the smaller boxes, and six main circuits from one box will generally be found to be as many as are convenient or desirable. This, assuming the average watts per circuit to be 5,000, would give us approximately 50 and 100 amperes respectively as the current in our distributors, and assuming that each main distribution box controlled six circuits.

It will be understood that these figures are only given by way of example to show the lines of procedure in working out a general scheme of practically any magnitude. In a smaller scheme, what we have called a distribution box would really be the main distribution box or switchboard, and in the smallest installation one sub-distribution box, as we have called it, would probably be the only unit. From this it will be seen that each distributing unit forms a self-contained installation, and the largest installation consists simply of a number of small installations linked up to a central distribution point.

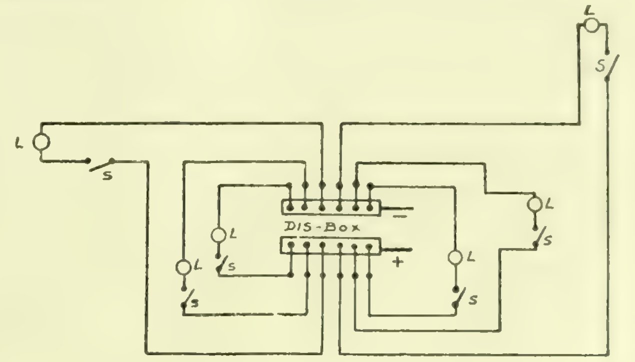


FIG. 1.—SIMPLE USE OF DISTRIBUTION BOX.

Although the foregoing description is intended to apply to an electric lighting installation, the principles set forth are equally applicable to an installation of electric motors; but in a motor installation, the question of the grouping of outlets does not generally arise, because, except for very small motors, it is customary and advisable to run a separate circuit from the distributing box to each motor.

In branching one conductor from another some kind of joint is necessary. For many years the usual method of jointing was to twist together, or splice, the conductors, having first thoroughly cleaned them, and, having spliced them, to solder or sweat them together, in order to ensure perfect electrical continuity. Unless carried out by a competent man this union is not always sound, and trouble ensues. Unless perfect continuity be maintained, heating of the joint occurs, and a risk of fire is introduced. Or the joint may deteriorate to such an extent as to interrupt the current. Owing to the unreliability of untrained wiremen, the difficulty of effective supervision, and the temptation to scamp jointing work in places difficult of access, jointing of conductors is now always reduced to a minimum, and the looping or "looping-in" method, as it is sometimes called, is very commonly used. In the looping method of wiring, instead of making a joint, the wire or conductor from which a tapping would otherwise be taken is supposed to be bent into the form of a loop and looped around a terminal in the fitting, switch, or ceiling rosette, to which the branch would in the ordinary way be taken.

In order to make clear the difference between the old-fashioned jointing method and the looping method, a simple case wired on the two methods is shown in Figs. 3 and 4. In Fig. 3 it will be seen that when a branch is taken off to a lamp outlet, a joint is made to each of the "feeds," and the pair of branch conductors are led down to the lamp (L) and switch (S) respectively. In one case two lamps are controlled by one switch, when, as will be seen, joints are taken from the branch

* Abstract of paper read before the Association of Engineers-in-Charge.

wires to one of the lamps. In Fig. 4, which represents a precisely similar circuit, there are no joints; but the feeds are carried down to the first lamp fitting and switch, looped around the terminals, and then carried forward to the next fitting, and so on to the end of the circuit.

The latter method obviously takes considerably more wire than is required in the old-fashioned jointing method. The difference in the quantities is not so great in straight rows of lights (such as might occur in a factory) as in irregular wiring, such as in domestic lighting, where one or two lighting outlets are fixed on the ceilings or walls in each room, controlled by wall switches, some of which may be of the two-way pattern. The extra cost of wires is, no doubt, counterbalanced to some extent by the saving in the cost of labour due to the absence of jointing, and the danger of faulty joints is minimised. But the looping method, as actually practised, is only looping in name. The conductors are not looped around the terminals without a break, as was, no doubt, the original intention, but they are cut at each point of connection, so that, instead of one, we have two conductors under the screw-heads or pinched up in the pillar terminals of fittings, switches, ceiling rosettes, and lampholders. Instead, therefore, of the uncertain soldered joint, we now depend upon the uncertain connection of two conductors held together by a pinching screw or under a screw-head.

When only one or two lights are wired on a circuit, there is, perhaps, no very great objection to the looping method; but looping is frequently carried to excess, causing unnecessary expense, complication, and risk. To take the very simple case shown in Figs. 3 and 4, it will be seen that on the old fashioned method (Fig. 3) the current to the last lamp does

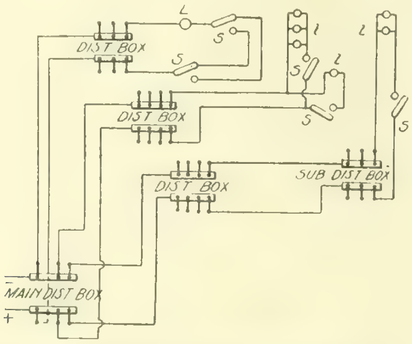


Fig. 2. Modern Method of Distribution.

not depend upon any joint, as the wires are not cut where the branches are tapped off, nor upon the contact of two wires in one screw terminal. On the more up-to-date looping method, shown in Fig. 4, the current to the last lamp passes through no less than six looping contacts, and on a larger circuit the number of such connections may be considerably more than this.

From the foregoing, it is clear that, while the looping method eliminates the defective joints of the unskilled wireman, it introduces a greater number of joints in the shape of mechanical connections, which are not always of an irreproachable character.

The means taken to protect cables depends upon the use to which they are put, the situations in which they are run, and the pressure of the circuit. According to the regulations which apply to factories and workshops, conductors must be so protected or placed as to prevent danger. This means that where they are placed high up in a factory so as to be put out of reach, they may be supported on insulators, and in places subject to steam or other moisture this method of running has its advantages. Cables, however, cannot always be kept out of reach; they must be run down walls or columns to switches and distribution boxes, and in such positions they must be mechanically protected. Apart from any metallic sheathing, such as of lead, copper, or iron, two methods of protecting the conductors are available, viz., metal tubing and wooden moulding.

The use of wooden moulding is necessarily limited to low pressure, that is to say, pressures not exceeding 240 volts normally, and to dry situations. Wooden moulding may be used in dry places, where not buried in plaster or cement, nor exposed to moisture, nor exposed to the drip from water pipes. It is, of course, inadvisable to use wooden moulding in any position where water may drip on it, such as under roofs, water-tanks, pavement lights, and the like, unless protected from drip in some way. For low pressures, and in dry situations, wooden moulding has done very good service, and even in damp places it has been extensively and successfully used when treated inside and out with a good coating of waterproof paint or varnish. Hundreds of sea-going ships have been wired in wooden moulding, which is regularly painted and becomes practically water-tight, and wires are taken out of such casings, after many years of service, in practically as good condition as they were when originally installed. The chief objection of wooden moulding, apart from its hygroscopic or moisture-absorbing properties, is its combustible nature. It is not fireproof, and if there is a bad place in the wiring, due, say, to mechanical injury in handling it, or to a badly insulated or badly made joint, there is always the risk of the insulation breaking down, or the joint overheating, or parting, and so introducing a fire risk, more particularly on the high voltages now prevalent.

For moist, steamy, and wet places, good lead-covered cables, properly installed, are hard to beat for durability and absence of leakage troubles. But it is no use going to the expense of lead covering and assuming that that is the end of it, and that it does not matter how the cables are erected and protected. Lead is a soft metal, and is not self-supporting, so that, unless adequately supported throughout its length, it will, sooner or later, give trouble. To cleat lead-covered cables up to a dead wall, or to suspend them from insulators just as one would support unsheathed cables, is simply a waste of good material, and is about as sensible as it would be to run rubber-covered wires in a baker's oven. Lead has the very useful property of forming insoluble compounds with certain acids and a thin coating of these forms a protective covering and renders the lead sheathing impervious to further chemical action. Tannic acid is, however, not one of these acids, and lead in its presence is readily attacked, and so is unsuitable for use in tanneries or for running underground near tree roots, unless specially protected. Acetic acid is another acid which has an affinity for lead, hence lead-covered cables should not be used indiscriminately in breweries and vinegar works.

In any position in which there are acids or vapours which may have a deleterious effect, lead-covered cables should not be used unless served with a stout protective layer of compounded tape. Lime in a dry state appears to have little or no effect on lead, but moist lime, on the contrary, attacks it slowly. Hence, while lead-covered cables may be run along dry brickwork with comparative safety, if run along a damp brick wall it will be found, before very long, that the lead is pitted or corroded wherever it touches a mortar joint, and, as soon as leakage commences, the lead will be rapidly eaten away. Apart from chemical action, lead suffers from the fact that, unlike most other metals, it is inelastic, and, instead of expanding and contracting with changing temperatures, it "creeps." By this is meant that in contracting lead does not always return to its original shape, but stretches and leaves some portions of the sheathing thinner than before, and repeated expansion and contraction may cause actual partition.

Let us make this clearer by assuming a concrete example. Take the case of a lead-covered cable laid vertically down a wall, and fixed by means of cleats at the top and bottom of the run. On a rise of temperature, the cable expands—that is to say, it elongates. Naturally, it will expand in the downward direction. On the temperature falling, the cable contracts; but as the lead has not the mechanical strength to pull itself up again to its original position, it contracts downwards, which results in the upper portion stretching. The amount of stretch depends, of course, upon the difference of temperature to which the cable is subjected; but, as there is a daily difference of temperature, there is a continual creeping downward, and it is only a question of time for the lead to become useless.

If we take the case of lead conductors supported horizontally by means of insulators or cleats, we get the same kind of action. On expansion, the cable sags between the supports, and on contracting it stretches at the supports and creeps down towards the middle of the loop. The only means of preventing this action is to support the cable continuously throughout its length, either by enclosing it in a wooden

moulding or by laying it on a wood batten, or by drawing it into an iron pipe, a method I am not favourably disposed to for inside work. Vertical lead-covered cables are not so easily dealt with, as, even if enclosed in a wood casing, the action goes on unless the lead is attached to the casing at frequent intervals, by means of ears or lugs soldered to the sheath in the same manner as is adopted for fixing lead water-pipes to walls. It will be understood that the action referred to is dependent upon the variations in temperature to which the cable is subjected and to the distance between the supports, the worst conditions being probably those which obtain in a pit shaft.

The foregoing remarks on the behaviour of lead apply both to rubber and to paper insulated cables, and in both cases the action is materially lessened by an iron or steel armouring over the lead. When lead-covered, steel-armoured cable is used, there should be a waterproof separator between the lead and the iron for the purpose of preventing electrolytic action between the two metals. For the same reason, plain lead-covered cables must not be laid on or in contact with iron.

For ordinary factory wiring and for public buildings and institutes, screwed barrel, or conduit, as it is now generally called, is very largely used, and, when well done, is a sound engineering job which is hard to beat. Conduit is not always of the screwed type, a large amount of wiring being done, where cost is a prime consideration, in what is commonly known as slip-socket conduit. This is practically identical in construction with bedstead tubing, and is made from steel strip bent into the form of a tube, the edges being brought close together, but not metallically joined. As this type of tubing cannot be screwed for sockets and fittings, it is not possible to make a sound metallic and mechanical connection between the various lengths, and it is not uncommon to find that, after a time, the joints part company, and the pipe is in place supported by the conductors instead of supporting them. Even when the work is put up in the best way, there is not that metallic continuity necessary for efficient earthing which screwed tubing gives. Owing to the open character of the seams and connections, this kind of tubing is quite unsuitable for damp situations and burying in plaster walls or in any place where moisture is present.

The question of using a screwed barrel, or conduit, system in moisture-laden atmospheres is one that has often been discussed, and opinions vary with individual experience. While some people have found the system quite successful, the experience of others has been most unsatisfactory. Few places are more difficult to wire satisfactorily than certain portions of paper mills, and an early experience of the author's with screwed gas piping (screwed conduit was then not a marketable commodity) was such as to make him very reluctant to repeat it. The pipes very soon became water-logged, and electrical leakage and short circuits soon followed as a matter of course. For work of this character, open work on insulators is preferable, at anyrate for the overhead horizontal runs. The vertical runs down to switch positions might be run in conduit, sealed at the top with compound and left open at the bottom to permit of condensed vapour draining away should any form in the pipes. A disadvantage of a mixed system of this kind is that we have a number of isolated pieces of metal pipe, any of which may become alive, as it is practically impossible to earth them short of running an earthing conductor all round the installation.

A water-tight piping system is sometimes advocated for the kind of works we are now considering; but, electrically speaking, there is no such thing. Think for a moment what it means. It means that not only all joints must be water-tight, but that the end of every pipe, inlet to a switch, to a ceiling rosette box, and all pipes leading into or from a distributing box must be hermetically sealed at the ends. And, supposing this to be even within the bounds of practicability, it has to be made sure that no moisture is imprisoned in the system, and means must be taken to prevent the ingress of moisture if at any time a pipe joint has to be broken for any purpose.

In a fairly extensive experience with screwed piping installations in factories of the so-called fireproof type—that is to say, in buildings constructed wholly of brickwork and masonry, or of ferro-concrete, in which there is a considerable amount of sweating and surface condensation—the writer has never had any trouble due to condensation in the pipes. This he attributes largely, if not entirely, to the fact that he always insists on a clear space of, say, half an inch being left between the pipes and the walls or ceilings to which they are attached.

A piping installation should be metallically continuous from main switchboard or supply terminals to the last lamp or motor on the system, so that if the switchboard or main service fuses are earthed the whole system is earthed. Men who are accustomed to make joints in water and steam pipes consider that no joint is perfect which is not well packed with a red or white lead mixture. But this is a poor sort of joint, from the point of view of electrical continuity, and it is preferable to paint the screw threads with an aluminium paint which is free from oil, and to make the couplings while the paint is wet. The paint should be applied to all that portion of the end of the pipe from which the enamel has been removed in order to prevent subsequent rusting.

The method of grounding as frequently carried out is quite inadequate. So long as a metal earthing clip is clamped around a pipe, and a copper wire of any size is run from it to a water pipe, around which it is twisted, it is too often assumed that all requirements have been met. Often one sees an enamelled iron clip clamped on to an enamelled conduit, or a brass clip many sizes too large touching the pipe at the two diametrically opposite points; or it may be a few turns of bare copper wire lapped round the pipe to which there has been a very ineffectual attempt to solder it, the net result being to practically insulate it therefrom with resin. For earthing, as for pipe connection, aluminium paint forms an excellent medium. After filing a clean place on the conduit, the place may be painted with the aluminium mixture and a

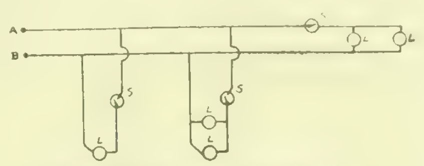


FIG. 3. OLD METHOD OF WIRING.

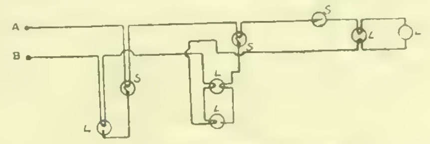


FIG. 4. LOOPING-IN SYSTEM.

substantial earthing grip attached to the prepared place. The same method may be applied to the waterpipe which forms the "earth." Earthing grips are now made which are serrated on the inside, and, when gripped up tight, the teeth bite into the iron, and make a very good contact. Even with these, a touch of aluminium paint before and after fixing will not be a disadvantage.

Not only must the pipe work be electrically continuous, but all metal work—whether switch-boxes, distribution boxes, motors, starters, and every piece of metal in which conductors are enclosed—must be considered as a part of the piping system, so that when the main switch or fuseboard is earthed, all these parts are earthed also. Manufacturers of such apparatus have, with a few exceptions, never fully appreciated these requirements; or, if they have, they have not turned out apparatus which permits of proper compliance therewith. Thus we have small ironclad switches and fuses with two smooth inlets and outlets for the cables, instead of one tapped boss top and bottom to receive a screwed pipe. When only one hole is provided, it is in rare cases that sufficient room is provided to permit of leading the cables into the terminals without dangerous cramping. In some designs, even by the most reputable firms, the iron cases are split across the cable inlets, which are provided with porcelain insulators to pass the cables through. This involves stopping off the pipes on each side of such boxes, bushing the ends, attaching earthing clips to them, and connecting these to the boxes by wires in any convenient way, which is generally by twisting them under the heads of the fixing screws. It is a tinker's job when all is done. Again, motor makers turn out motors intended for 400-volt circuits without terminal boxes. In some cases they adopt the hateful American practice of leaving tailpieces sticking out with brass sweating sockets on the ends. How in this world they expect a wireman to connect his cables up to these, and at the same time maintain

metallic continuity between the pipework and the motor case, is known only to themselves.

Lighting distribution boxes are made both in hard wood and cast iron, both types being used on piping installations. When wood boxes are used, means must be taken to preserve continuity of the piping system. This can be done by fixing iron plates top and bottom, drilled to receive the inlet and outlet pipes, and bonded together by means of a copper tape. For domestic purposes the wood box has its advantages, as there is less risk of the uninitiated receiving a shock in replacing a fuse than is the case with an iron box. It is common manufacturing practice to connect the fuses directly to the bus-bars in the distribution box, a practice which involves connecting the circuit switches on the lamp side of the fuses, which, therefore, cannot be made dead without making the box dead. It is very desirable, therefore, to have fuses which can be safely handled when replacing a live bar.

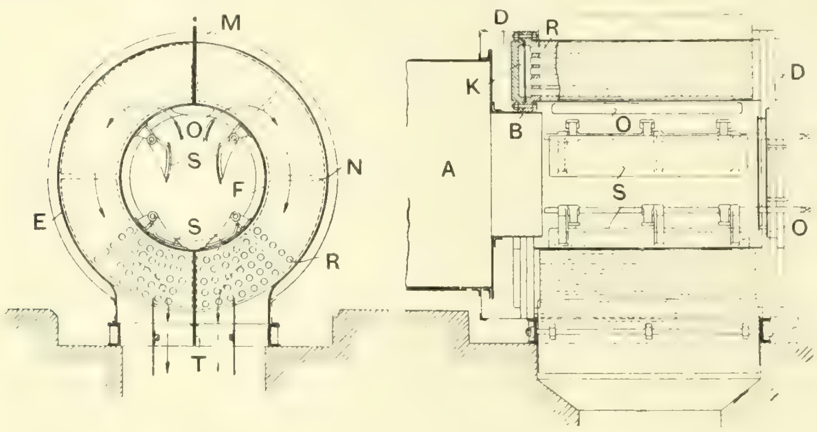


Fig. 1. Fig 2
Wolf's Feed-water Heater

Double-pole switches are now generally of the knife pattern, and there is a difference of opinion as to the desirability of passing the current through the hinges. When this is done it is important to connect the live ends of the cable to the clip contacts and not to the hinges, so that the knife blades are dead when the switch is in the "off" position; otherwise, besides the risk of touching the live blades when in the "off" position, there is the risk of their "shorting" on to the lid of the box.

Touching on main switchboards, one might point out that in those open designs which have back connections there must be a clear space of three feet between any live connections and the wall at the back, and this may involve taking up useful space. For low pressures a skeleton type of board may be used, in which all connections are accessible from the front, and these, if well made, make a very nice looking piece of apparatus. For factory work, however, a complete ironclad type of board, while perhaps not quite so ornamental as a white marble board with highly polished and lacquered fittings, makes a more engineering looking job.

Overwinding Accident at a Colliery.—An alarming accident occurred on Monday last at Bersham Colliery, near Wrexham. The winding gear, it appears, went wrong, and the cage crashed into the pithead, two men having narrow escapes. The engine house was wrecked, and a large number of men will as a consequence be thrown out of work.

South Staffordshire Iron and Steel Institute.—At a meeting of the South Staffordshire Iron and Steel Institute, at Dudley, on Saturday last, Mr. R. A. Brown read a paper on "The Re-Solution of Carbon in Solid Cast Iron." In introducing his subject, he said that in gray pig-iron the greater part of the carbon existed in the form of graphite, which was an extremely infusible substance. When the iron was re-melted this carbon was dissolved at some temperature below the melting point of the cast iron as a whole, and evidently, therefore, graphite must be soluble in solid cast iron. It might possibly exist in solution as elemental carbon at this high temperature, though it was generally believed to be present in the form of carbide of iron, dissolved in the iron. The object of his researches had been to determine the extent to which graphite was soluble with solid cast irons and the influences which governed this solubility. It was hoped, if possible, to corelate density changes with the expansions recorded by Keep, Turner, and other observers.

WOLF'S FEED-WATER HEATER.

The accompanying illustrations show a design of waste-gas feed-water heater with straight water pipes opening on both sides into annular chambers, in which the gas is supplied through openings in the inner casing of the heater and discharged through openings in the outer casing, the invention of R. Wolf, Magdeburg-Buckau, Germany. The working of such a waste-gas feed-water heater depends chiefly on the permanent cleanliness of the heating surfaces in contact with the water as well as of those in contact with the heating gas, and on the existence of a sufficient velocity of the heating gas. These requirements are complied with in the construction under notice partly by arranging two partitions diametrically opposite each other in the casings, at least one of the partitions being adjustable, and by providing separately adjustable passages, next to the partitions, in the two casings of the feed-water heater, so that there are produced two feed-water halves independent of each other, one of which can be cleaned, without interrupting the working, either on the side in contact with the water or on that in contact with the heating gases, and the two halves can be connected either in parallel or in series for the purpose of ensuring the most favourable velocity of the heating gas at the time. When connecting in series in the case of a small load, the transmission of heat is considerably increased, whilst in the case of a high load the two halves are connected in parallel for the purpose of obtaining a greater quantity of heating gas. The different connection of the two heater halves is effected by means of flaps or slides.

Fig. 1 shows the apparatus in cross-section, the two feed-water heater halves being connected in parallel. Fig. 2 is a partial longitudinal section. Fig. 3 shows diagrammatically the connection in series of the two heater halves, whilst Fig. 4 shows one heating surface of the heater inoperative, for the purpose of cleaning. The heater is connected direct to the boiler or its super-heating casing A, and the straight tubes receiving water and in contact with the heating gases, are arranged on the same side as the heating gas inlet branches B and inserted at both ends into annular water chambers K which, for the purpose of facilitating the cleaning of the heater tubes from dirt and scale, are provided with annular covers D after the removal of which all the tubes can be cleaned by cleaning tools throughout the whole of their length. The annular space filled by the tubes R between the outer casing E and the inner casing F of the heater, is divided into two halves by two removable plates M and T arranged diametrically opposite each other. The inner casing F is pro-

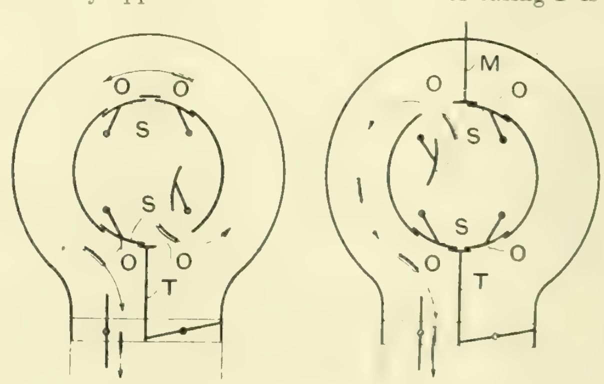


Fig. 3 Fig. 4
Wolf's Feed-water Heater

vided with passage openings O, one in each quarter of a circle, these openings being closed by flaps S pivoted. By means of these flaps the two heater halves can be connected in parallel as shown in Figs. 1 and 2, or in series as shown in Fig. 3. In the latter case one separating plate M is withdrawn. With this arrangement, each heater half can be completely switched out, as shown in Fig. 4 for the purpose of thorough cleaning. In order to enable one heater half to be cleaned without interrupting the working of the outer half, the annular covers D (Fig. 2), which enable the heating surface in contact with water to be uncovered, are divided. Moreover, the outer casing E is divided and removable.

THE WORLD'S OUTPUT OF ELECTRIC STEEL.

THE world's production of steel ingots and castings by the electric process is reported by the Comite des Forges de France as having amounted to 126,476 tons in 1911, as compared with 120,116 tons in 1910 and 47,039 tons in 1909. Kershaw estimates the output in 1908 at about 30,000 tons. The French Association prints a table giving the annual output by Germany and Luxemburg, the United States, Austria and Hungary, and France from 1909 to 1911 inclusive. This table, however, is not complete, as the production of electric steel by Sweden in the three years is not included. Nor does the association include the output of electric steel by Italy, Great Britain, Norway, and Switzerland, all four of which made steel by this process in recent years. In addition, Spain, Belgium, Russia, Mexico, and Japan are reported to have been looking into the merits of the electric process for making steel, and some of these countries may have also produced small quantities of electric steel in 1911 and perhaps in some earlier years.

Italy has made steel by the electric process regularly since 1903. In 1911 there were four electric furnaces in operation in that country, as compared with two furnaces in 1910 and five furnaces in 1909. At least small quantities of steel by the electric process were, therefore, made in all three years. No figures for any year seem to be available, however.

Great Britain also made considerable quantities of electric steel in 1911, and, perhaps, in some earlier years. A 2-ton Heroult furnace has been in operation for some time at Braintree making steel castings for automobiles. Electric furnaces are also being operated at Sheffield by Verdon Cutts and Hoult, the Edgar Allen Company, John Brown and Co., William Jessop & Sons, Vickers, Sons, & Maxim, and Thomas Firth & Sons. While the furnaces operated by these companies are all of small capacity, their product being chiefly steel of a special character for tools, &c., their united output would probably amount to several thousand tons annually. At Carlin How in Yorkshire a 15-ton Heroult furnace is being built, which will, it is said, manufacture steel for rails and will considerably increase the annual output of electric steel. The Stobie Steel Company, Sheffield, is now erecting a plant there, which is being equipped with five electric steel furnaces—two 15-ton, two 5-ton, and one 3-cwt., the latter to be used as an alloy melting furnace. Some of the electric furnaces in Great Britain use molten metal from open hearth furnaces, while others make steel from cold scrap. Statistics of the production of Bessemer and open-hearth steel ingots and castings only are annually collected in the United Kingdom, the manufacturers declining to report to the British Iron Trade Association their annual output of crucible and electric steel ingots and castings.

In Sweden in 1911 there were 13 electric furnaces in operation, as compared with 12 in 1910, and 11 in 1909. The production of these furnaces in 1909, 1910, and 1911 will be found in the table given below.

Norway has made steel by the electric process since early in 1910, a 5-ton furnace having been put in operation at Jossingfjord in the spring of that year. It is reported that a 30-ton furnace is now being added.

Germany first reported the manufacture of electric steel in 1908, in which year the output was 19,536 metric tons. As shown by the table, the production of steel by the electric process in Germany in 1911 amounted to almost one-half of the total output reported for the world. The number of furnaces that made electric steel in Germany in 1911 was 15, as compared with 13 in 1910 and eight in both 1909 and 1908.

France has also reported the manufacture of electric steel since 1908, in which year the quantity was 2,686 metric tons. For 1911 the number of active electric furnaces is not available, but in 1910 there were 21 furnaces in operation, against 12 in 1909 and seven in 1908. In the first six months of 1912 France made 7,920 tons.

Austria first reported the manufacture of electric steel in 1908, when 4,333 metric tons were made. In 1909 the output was 9,048 tons; in 1910 it was 19,672 tons, and in 1911, 21,606 tons. Hungary appeared as a maker of electric steel for the first time in 1910, when 356 metric tons were reported. In 1911 the output was 1,261 tons. The number of electric furnaces active in Austria and Hungary in these years is not available. A 2,000-kg. electric furnace is now being installed at the Konigliche Ungarische Staatseisenwerke, at Diosgyor, Hungary.

Switzerland has also been manufacturing steel by the electric process for some time. It has one furnace of about two tons capacity.

In the United States steel by the electric process was first produced in 1908, the output amounting to 55 tons, made by one plant. There is likely to be a considerable increase in production in the near future, although in the first half of 1912 the output is reported by the American Iron and Steel Institute at only 6,882 tons, a surprisingly small total. At the present time 11 plants in the United States are equipped with electric furnaces. In addition five plants are now installing electric furnaces or have placed contracts for their installation. The number of works that made electric steel in 1911 was nine, against seven in 1910, four in 1909, and one in 1908.

The table which the Comite des Forges de France has compiled is given below. The output of electric steel in Sweden for the three years has been added. Gross tons are used for the United States and metric tons for all foreign countries.

	1909 Tons	1910 Tons	1911 Tons
Germany and Luxemburg	17,773	36,188	60,654
Austria-Hungary	9,048	20,028	22,867
United States	13,762	52,141	29,105
France	6,515	13,445	13,850
Sweden	591	431	2,034
Total	47,689	122,233	128,510

With the exception of the United States, all the countries named in the table show an encouraging growth in the three years. In this country the output in 1911 fell off from that of 1910 by over 44 per cent. Germany, on the other hand, shows an increase of 24,466 tons, or over 67 per cent.

Of the total production of electric steel in the United States in 1911 about 27,227 tons were ingots and about 1,878 tons castings. Almost all such steel made in this country is taken to the electric furnaces in a molten condition from Bessemer converters, open-hearth furnaces or crucible furnaces. On the Continent, however, and to some extent in Great Britain, cold metal is usually charged in the furnaces and melted by electricity. Of the 29,105 tons of electric steel made in the United States in 1911 over 6,700 tons were alloy steel. In the same year 462 tons of rails were rolled from electric steel.—"The Iron Age."

CALORIFIC VALUE OF LIQUID FUELS.

IN the course of a paper on the chemical examination of fuels recently delivered at the University of Liverpool, Mr. Patterson furnished the following interesting table giving the calorific values of various liquid fuels, as determined by the Mahler bomb calorimeter:

	Description.	Specific Gravity	Carb.	Hyd.	Sulph.	B.T.U.
1	Oil used at trial of torpedo-destroyer	0·921	85·28	11·93	0·55	17,975
2	Petroleum product (a little over £2 per ton)	0·888	86·20	12·57	0·31	18,175
3	Ordinary crude petroleum as used for Diesel engines	0·923			0·45	17,921
4	"Light fuel oil"	0·900	85·58	10·81	0·43	18,205
5	"Admiralty fuel oil"	0·928	86·40	11·55	0·34	17,930
6	"Residuum"	0·943	86·44	11·23	0·30	18,117
7	"Black oil"	0·928	86·44	11·83	0·51	17,959
8	Refined oil specially adapted for Diesel engines	0·904	85·05	12·15	0·37	17,996
9	Crude Roumanian	0·825			0·20	17,863
10	Ditto	0·830	83·77	12·98	0·29	18,022
11	Solar oil Texas .. .	0·862	85·35	12·92	0·17	18,344
12	Scotch shale oil	0·855	86·16	12·37	0·26	18,248
13	Ditto	0·862	85·35	12·44	0·29	18,317
14	Ditto (works well with Diesel engines)	0·867			0·33	17,930
15	A coal tar oil	0·958	86·16	9·05	0·30	16,960
16	A gas oil (gives trouble with Diesel engines)	1·067	87·62	5·98	0·67	16,153
17	A gas oil	1·004	83·72	7·29	0·82	15,977

DEVELOPMENTS IN THE PREPARATION OF IRON ORES.[*]

BY J. W. H. HAMILTON.

(Concluded from page 214.)

ALTHOUGH ferro-titanium and titanium steel are used in large quantities, the titaniferous iron ores are not yet considered a commercial product. Various attempts have been made to improve the titaniferous ores by magnetic separation, but it has been found impossible to make a high grade concentrate without losing too much iron in the tailing. If the titanic acid does not exceed 3 per cent., the ore can be smelted in the blastfurnace without any trouble, but if the titanic acid is higher, the slag gets sticky and difficult to handle, unless special precaution is taken in preparing the burden. Experiments have been made by Rossi, who has demonstrated that under certain conditions ores of higher titanic content can be successfully smelted ; but no such ores are at present worked on a large scale. As there are large titaniferous ore deposits containing over 50 per cent. of metallic iron, there is no reason why these ores should not be utilised by mixing them with other ores and thereby bringing the titanic acid in the mixture within such limits as are not objectionable for the blastfurnace. A great many of these ores can be mined cheaply and can be cobbed at a small cost by magnetic machines. The iron content in the cobbed product would be sufficiently high to make the ore desirable for mixing with other ores free from titanium. If a company operating on a large scale systematically mixed a certain portion of titaniferous ores with all ores shipped, it would, in many cases, be in a position to utilise without any detriment to the furnace operation as large a proportion as 25 per cent. of the titaniferous ores now considered undesirable.

Some hard hematites are mixed with magnetites. Such ores generally are crushed and sized and first treated on magnetic separators. The tailing from these machines is concentrated on jigs. If the ore contains only hematite it is hydraulically-concentrated. The recovery on jigs is not so high as on the magnetic separators. In the former it is considered good work if the iron content in the tailing does not exceed 12 per cent. ; in the latter it is often brought below 5 per cent. Jigging plants for hematite have been erected recently at Bathurst, New Brunswick, and Annapolis, Nova Scotia, and several plants are in operation at the Swedish mines.

The sandy and clayey ores are treated principally by washing or a combination of washing and jigging. Log washing is an ancient art, and there has been little development in the process, apart from the introduction of shaking tables for treating the fines. The improvements that have been made lately pertain principally to mechanical features in the construction of the machinery and the mills. The washing plant of the Oliver Iron Mining Company at Coleraine, on the western Mesabi range, is a notable example of modern mill construction. An interesting feature of this plant is that, although it has been built on level ground, the ore is never raised by either elevator or inclined belt conveyer. The ore trains are run over a high trestle into the top storey of the plant and the ore is discharged from bottom-dump cars into receiving bins that are sufficiently high to allow the material to drop by gravity from one machine to the other all through the plant, until it is finally discharged into the shipping bins. The concentrate from the tables, which is delivered to the bins by means of Frenier spiral pumps, is the only ore that has to be raised to the bins by mechanical means. The plant is built in five units, and provision has been made for extension. Its capacity has never been definitely ascertained. Over 20,000 tons have been washed in a day without loading the machinery up to capacity. Aside from the men employed at the picking belts, very little labour is required. As the ore is not crushed and, therefore, contains pieces too large for jigging, the over-size, after thorough washing in the revolving screens, is fed to wide, slow-moving belts, where the rock is picked out by hand. What goes through the screens is washed in log washers built entirely of iron and steel. The fines are treated on Overstrom tables.

In connection with these plants it might be well to mention that in mill construction in general the improvements that have been made during the last few years are extensive. The crushing machinery has been much improved and the cost of crushing has been reduced by about one-half. Elevators, which used to give daily troubles to mill men, are built now so that they can run for years with little attention. Transmissions and milling machinery in general are built stronger and provision is made for heavy overloads.

Although wet processes have been almost universally employed for the concentration of hematites, dry methods have also been used. A treatment of that kind has been developed by E. F. Goltra, and a plant utilising it has been built at Waucon, Wis. The principal features are the heating and trommeling of the ore in a cylinder similar to a rotary drier, and the removal of the gangue and clayey dust by a strong air blast, created by a powerful suction fan connected to the charging end of the kiln. The air current and combustion gases and the material travel in opposite directions. It is too early to give any results from this process, but it has merits and will probably give satisfaction on certain kinds of ores.

Many magnetite ores carry apatite in the gangue. Such is the case with the Old Bed ores at Mineville, also with many of the Swedish ores. At Mineville most of the phosphorus is eliminated by magnetic separation, and the tailing, which contains, besides the apatite, several more or less weakly magnetic minerals, is cleaned on strongly magnetic Wetherill separators. Part of the apatite concentrate, containing over 40 per cent. bone phosphate, is sold to fertiliser works, but as only the high grade apatites are suitable for treatment by the acid method, the market for low grade product is limited. To utilise, also, the low grade material, Dr. W. Palmer has developed an electrolytic process by which it can be converted into a high grade fertiliser. A plant on a commercial scale is now in operation at Trollhattan, Sweden, and in this plant some of the phosphorus magnetites from the mines in Lapland have been successfully treated. It is possible to treat either the tailings from separating plants or the crude ore. At the Kiruna mines in northern Sweden, there are enormous deposits of magnetites containing about 56 per cent. iron with a gangue composed almost exclusively of apatite. When this ore is treated by the Palmer process, the iron content is raised to 71 per cent. and the phosphorus is lowered to 0·03 per cent.

In the United States hard ores are roasted only when they are high in sulphur, but the practice in Sweden is to roast nearly all lump ores. As charcoal is used there almost exclusively for making pig iron, it is necessary to economise this expensive fuel, and for that reason the ores are roasted not only to eliminate sulphur, but also to oxidise them and make them more porous. When some of the hard ores are crushed they produce so much fines that the roasting becomes difficult in ordinary furnaces. At the Oxford furnace in New Jersey, to avoid this trouble, the ores used are screened and the fines are roasted separately in Wedge rabble furnaces.

Few of the fine-grained soft ores are suitable for smelting in their crude form. Still, they are used in large quantities, and a comparatively small proportion is transformed into a suitable lump form. Increasing interest has recently been shown in the processes for treating these ores preliminary to smelting. The good results obtained at the furnaces that are now operating with the improved ore are so obvious that it will be an inducement for those who are troubled with fines to transform at least part of them into suitable lump form. The most common methods of treating the fines are nodulising, briquetting, and sintering.

The nodulising process was first used on a large scale for desulphurising and agglomerating pyrites residues at the plant of the Eastern Nodulising Company, Hackensack Meadows, N.J. It is now used on nearly every kind of ore. The product of nodulsing kilns is a good blastfurnace material, but the nodules are more glazed and not so porous as the products from some of the other processes. The Penn-

[*] Paper presented at the Pittsburg meeting of the American Iron and Steel Institute.

sylvania Steel Company, at its Lebanon, Pa., plant, is nodulising magnetic concentrates from the Cornwall ore. Several plants have been built for the nodulising of flue dust, for instance that at Hubbard, O., and the plant of the Illinois Steel Company, South Chicago. A plant for treating siderites high in sulphur has been built at the Magpie mine, Michipicoten, Ont. Here the carbon dioxide as well as the sulphur is driven off. The largest nodulising plants are those treating Cuban brown ores in the province of Oriente, Cuba. The Mayari and Moa ores contain as much as 14 per cent. chemically-combined and 25 per cent. hygroscopic water. By the nodulising of the ores they are reduced nearly 40 per cent. in weight. Some of these ores are now being treated in Greenawalt sintering plants, built by the Pennsylvania Steel Company, at Sparrows Point, Md., and Steelton, Pa.

To reduce freight charges some ores are dried in rotary kilns. Plants for this purpose have been built at the Hollister mine, Crystal Falls, Mich., and at the Brunt mine and Mountain Iron on the Mesabi range. The moisture content of the hard ores is negligible, but the soft ores can absorb as much as 25 per cent. of water. After the ore has been dried some moisture may be reabsorbed during transportation, but the amount is small, considering that from the time the ore is shipped until it reaches its destination the rainfall seldom exceeds a fraction of an inch.

The first successful briquetting system for iron ores was developed by Dr. Grondal, who worked principally with fine-grained magnetic concentrate. This material is particularly well adapted for briquetting. The principal features of properly made Grondal briquettes are that they have no artificial binder and can be subjected to heat without disintegration; they are not vitrified, but are very porous and easily penetrable by the reducing gases; they are strong and can be handled without going into fines; they are nearly free from sulphur even if the sulphur content in the crude ore is as high as 2 to 3 per cent.; they are highly oxidised and the magnetite is transformed into hematite; they are easily reducible in the furnace and require comparatively little fuel.

Fine ores of nearly all kinds are now briquetted. Over 500,000 tons of briquettes are yearly produced from magnetic concentrate in Sweden and Norway. Large quantities of limonites are briquetted in Spain, and pyrites residues in England and the United States. During the past year a four-kiln plant has been in operation in Mayville, Wis., briquetting Mayville ore. The briquettes are used at the furnaces of the North-western Iron Company, where the advantages gained by briquetting fine ores have been well demonstrated. Only part of the ore is briquetted, and about 30 per cent. of the burden is made up of briquettes. The advantages gained are many. The amount of flue dust has been greatly reduced, resulting in a higher efficiency and a longer life of the stoves; the hanging and slipping have been eliminated, whereby good control of the furnace has been obtained, and a uniform product is produced; the life of the lining is much prolonged; the output of the furnaces has been increased without corresponding increase in labour and the grade of pig iron has been improved.

The application of blast roasting to the sintering of fines and flue dust is the latest development in the preparation of iron ores. The Huntington-Heberlein process, which is successfully used for roasting sulphides, has not been found so effective for sintering fines as the two down-draught processes, both of which are now employed on iron ores. The continuous system developed by Dwight-Lloyd for the treatment of copper sulphides and flue dust is now successfully working on iron ore flue dust. At the plant owned by the American Ore Reclamation Company, Birdsboro, Pa., experiments have been made with various kinds of ores, all of which have been sintered successfully. In the flue dust there is often enough coke to sinter it without the addition of any other fuel, except that required for ignition. If there is an excess of coke it is best, in order to get the full benefit of it, to mix in some fine ore free from fuel. The sinter produced makes a good blastfurnace material. It is porous and offers a large surface to the reducing gases.

The Greenawalt sintering process has been referred to in connection with the Cuban ores that are sintered by the Pennsylvania Steel Company at its Steelton and Sparrows Point plants. The Greenawalt system is intermittent. The ore is mixed with fuel, generally in the form of crushed coal or coal screenings, and is charged in large shallow pans in which the grate bars are placed from 10in. to 12in. from the top. The charge is made level with the top of the pan and an igniter carried on a track is placed over it. The pan is suspended on hollow trunnions connected to an exhaust fan, which is started as soon as the oil burner in the igniter is turned on. In less than a minute the reaction has spread all over the surface. The igniter can then be removed. It takes from 15 minutes to one hour, depending on the nature of the material, to complete the sintering of a batch. When the reaction has reached the porous bed, which is a layer of inert sintered material spread on top of the grate bars for their protection, the suction fan is shut down and the pan is tilted to allow the sintered material to drop out on a grizzly or directly into the railway cars. The pan is then returned to a horizontal position and is ready for the next batch. The capacity of the pan depends much on the nature of the material. From some ores as much as 100 tons can be produced in 24 hours in a 7ft. by 12ft. pan. From other ores only 50 to 60 tons can be produced.

Some interesting features have been noted during experiments with this process. It has been found to be of importance to have the moisture content in the ore within certain limits in order to obtain good results. Some ores, for instance magnetic concentrate, require about 7 per cent. of moisture, whereas others, as for instance pyrites cinder, sometimes require over 20 per cent. Some ores can be sintered in about 15 minutes and others require as much as an hour.

The desulphurisation by this process is very good, provided that the fuel is not used in excess. If an ore is high in sulphur, little or no coal should be added, and the less coal is added the more complete is the desulphurisation, provided that the ore contains enough fuel for the necessary combustion. Experiments have been made with a magnetite ore containing $1\frac{1}{2}$ per cent. of sulphur in the form of pyrrhotite. With the addition of only 2 per cent. of coal, a good sinter containing 0·05 per cent. sulphur was produced. Other ores in which the sulphur has been combined with calcium and barium, forming gypsum and barium sulphate, combinations which in ordinary roasting furnaces are very difficult to break up, were successfully desulphurised. To obtain good results it was found necessary to use barely enough fuel to agglomerate the charge without fusing it into vitrified masses that would be impenetrable to the gases. If an insufficient amount of fuel is used, the sinter becomes soft and, to a large extent, goes into fines. If an excess of fuel is used, the sinter becomes glazed and, in spite of its honeycombed nature, loses in porosity. It is not possible to avoid all vitrifying and still make the sinter strong enough for transportation and handling, but it can be reduced to a minimum if the fuel is correctly proportioned. A noteworthy feature found during these experiments is the remarkably low fuel consumption.

Fatal Steam Pipe Explosion on a Steamer.—On Monday night last as the steamer "City of Liverpool" was proceeding down the Manchester Ship Canal between Moore and Runcorn a steam pipe burst in the engine-room, one man being so severely scalded that he subsequently died.

The Fatal Biplane Accident on the Thames.—An enquiry was held at Gravesend on the 21st inst. into the circumstances of the death of L. F. MacDonald, the aeroplane pilot, who fell with his mechanic and a Vickers biplane into the Thames at Joyce Green, near Gravesend on January 13. Explaining the probable cause of the accident, Mr. Archibald Law, chief designer in the aviation department of Messrs. Vickers, said that from an examination of the wrecked machine on its recovery from the river three weeks after the mishap, he considered that owing to the cold weather the oil in the engine had become frozen, and the lack of lubrication acted as a brake, interfering with and finally stopping the engine. It was only run for two minutes prior to the flight, whereas it was necessary to run ten minutes to warm the oil when it had become frozen. The same fact probably accounted for the aeroplane flying so low that it was unable to plane as far as the shore when the engine stopped running. A verdict of accidentally drowned was returned.

PACKING DEVICES FOR ROTARY ENGINES.

SEVERAL improvements in rotary engines and pumps have been introduced and patented by Mr. F. A. Parsons and Mr. J. H. Myers, 439, Court Street, Binghamton, New York. These relate mainly to the packing employed for the purpose of preventing the leakage of motive fluid, and are shown in the accompanying cuts, of which Fig. 1 is a central vertical section of the engine with the packing in place; Fig. 2 is a section on the line X—X of Fig. 1; Fig. 3 is an inside elevation and partial section of one of the end plates of the casing, and Fig. 4 is a perspective view of a detail showing a portion of the packing ring, the wedge block behind it, and the screw and spring for projecting the block.

The rotary engine comprises a casing A through which passes the main shaft B carrying the eccentric piston C, the latter having oppositely disposed radial pockets or recesses D in each of which is mounted a series of sliding blades E

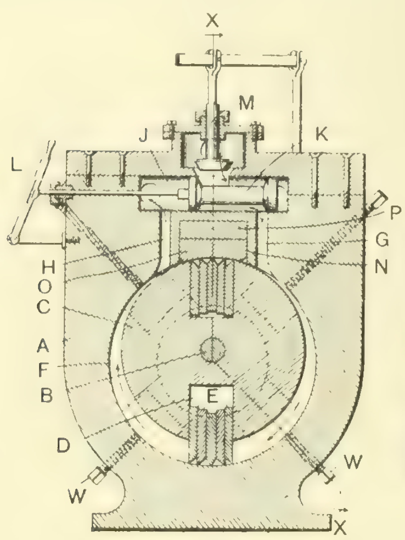


FIG. 1

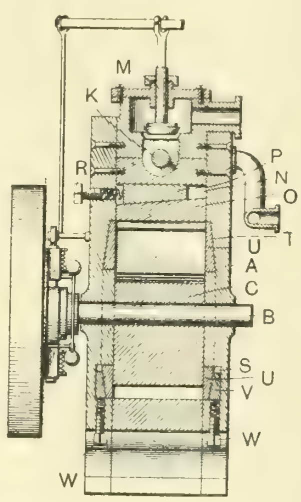


FIG. 2.

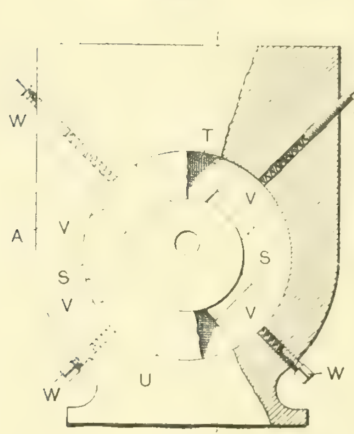


FIG. 3.

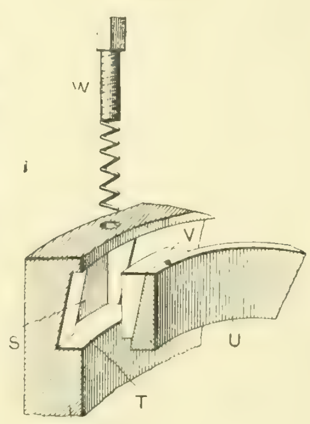


FIG. 4.

PACKING DEVICES FOR ROTARY ENGINES.

which are thrown radially outward by centrifugal force into steam-tight engagement with the inner wall of the piston chamber F. Cored through the casing and opening into the top of the piston chamber F near its highest point where the piston C contacts with it, are the inlet and outlet ports G H, whose upper ends communicate with the valve chamber J, within which is located a double valve K whose position is controlled by a hand lever L by means of which it can be set to run the engine in either direction. The admission of steam to this chamber is controlled by a valve M between it and the steam chest, and this valve in turn is operated by mechanism connecting it with the main shaft B and with a governor thereon. In brief, when the valve K is set as herein shown, steam admitted from the steam chest follows the arrows and rotates the piston in the direction shown, and during its revolution the blades E are thrown outward from the axis by centrifugal force.

The casing has a recess N between the two ports G and H, and within this recess is disposed a wear block O whose curved inner face is forced normally inward with gentle pressure by means of a wedge P, located within the recess behind the block and somewhat shorter than the latter, as seen in Fig 2, the inclined or bevelled faces of these members being in contact. A spring bears against the larger end of the wedge at one extremity, and a set screw R bears against the other extremity of the spring, whereby the tension of the latter may be increased as desired; and the constant expansion of this spring pushes the wedge slowly inward so that the wear block is forced gently toward the axis of the chamber F to take up for wear which occurs on the periphery of the piston C and the outer edges of the plates E. Some provision must necessarily be made for preventing the inflowing steam from leaking past the piston and its packing into the outlet, without pressing into and around within the piston chamber and performing its work, and the packing above described performs the desired function for the peripheral edge of the piston itself. Both ends of the piston are also in need of packing to prevent the passage of steam by them without doing its work, and as the arrangement for overcoming leakage at these points is the same at one end of the piston as at the other, only one will be described. Cut into the inner face of each end wall of the casing A at about four points equidistant from each other around the axis of the piston chamber F are radial recesses S, all four of the set or series communicating with an annular channel T cut into the face concentric with its axis. In the channel is disposed a packing ring U and in each recess is disposed a wedge V, the bevelled or inclined faces of these members being adjacent each other, as seen in Fig. 2. The various wedges, like that behind the wear block above described, are borne normally in a direction to increase the pressure of the ring U upon the end of the piston, by means of springs, while set screws W pass radially inward through the casing for adjusting these springs. Thus, it will be seen that both ends of the piston (near its periphery and for some distance inward therefrom) are protected against leakage by the constant inward pressure of the rings U. The spring-pressed wedges behind these rings are constantly setting the latter further inward and as the ends of the pistons wear away, and in spite of all this if leakage should occur, the operator may set up the screws W from time to time, as necessary. The inclination of the bevel faces on those parts which contact with each other is made rather slight, first because the less the inclination the greater the ease of adjustment, and second because the packing members should not be forced outward by their own expansion nor by the expansion of steam.

THE DESIGN OF AIR COMPRESSORS.

IN a paper on this subject read before the Northampton Polytechnic Institute Engineering Society, on February 21st, Mr. D. Gilbert said that compressed air was used by Smeaton for tunnelling work late in the eighteenth century. Since then it had found a prominent place in all submarine and subterranean work, and comparatively recently for the transmission of power and in the operation of pneumatic tools. The thermo dynamics of air compression was governed by the well-known gas equations, and the ideal cycle of operations for any compressor was the reversed Carnot cycle. The object before the designer of an air compressor was to obtain the maximum output of air at the required pressure with a minimum input of energy. Theoretically, this was obtained by isothermal compression. In practice this was impossible. Theoretically, the maximum amount of work expended in the compression of a given volume of air took place when the compression was adiabatic. In practice this was also impossible, nor, of course, was it desirable. The actual compression was neither isothermal nor adiabatic, for the following reasons: It was impossible to compress air without raising its temperature, and the cooling systems in vogue, not being efficient, all the heat generated could not be extracted. But the cooling systems, not being entirely inefficient, extracted some of the heat. The compression curve would therefore be represented by the equation $p\,v^n = k$, where the value of n varied between 1 and 1·408.

The effect of clearance on the power absorbed by a compressor was of very little consequence if there was no leakage,

for the energy taken up in compressing the air into the clearance volume was given up to the piston on re-expansion. But its effect on the volumetric efficiency of the compressor cylinder was very important. The air compressed into the clearance volume on the power stroke re-expanded on the retirement of the piston, and until the pressure inside the cylinder had reached that of the external supply no air could be drawn into the cylinder, and thus a part of the suction stroke was wasted. The wasted part of the stroke obviously depended upon the magnitude of the clearance volume, which must therefore be kept as low as was consistent with safety in prevention of knocking. By equalisation valves the effect of clearance volume on volumetric efficiency was reduced. By this means the high-pressure air in the clearance volume at the end of delivery was allowed to flow to the opposite end of the cylinder until the pressures were equal on both sides of the pistons. Re-expansion consequently started nearer the atmospheric pressure and did not occupy so large a fraction of the suction stroke. But, although the volumetric efficiency was thus increased, it was brought about at the expense of power used in compression, and for this reason this type was not often adopted.

The compression curve nearest to the isothermal was obtained in the early compressors when compression was effected by the water piston. This was simply a column of water forced to rise in a cylinder containing air, thus compressing it. The air being in immediate contact with the water, gave up a great deal of its heat to the water. But with the introduction of the mechanical piston and higher speeds the water pistons went out of use, and the water spray was substituted. This system was fairly efficient, but its accompanying disadvantages caused it to be generally dropped. The almost universal system of cooling was now by water jackets around the walls and covers of the cylinders, and also around the valve pockets. But this system was extremely inefficient, and in some cases only produced a very small reduction in temperature of the air delivered. The main causes of this were: (1) Air was a bad conductor of heat. (2) The cylinder walls, &c., were also imperfect heat conductors. (3) The ratio of cooling surface to heat generated was not constant throughout the stroke, diminishing as the stroke increased.

The chief reasons for multi-stage compression were: (1) Prevention of high temperature delivery. (2) Better volumetric efficiency obtained. (3) Economy of power. The operation of a 2-stage compressor was as follows: Air at atmospheric temperature and pressure was drawn into a low-pressure cylinder and compressed to a higher pressure, with resulting increase in temperature. The compression tended to approximate to an adiabatic one. The air was then passed through an inter-cooler, its temperature and volume being thereby reduced. This new volume was then drawn into the high-pressure cylinder, where it was further compressed approximately adiabatically. The economy was effected in a negative way. It was brought about by reducing the power wasted. If the compression had taken place in one stage the resulting curve would have been a continuous one. The area between this curve and an isothermal plotted to the same base gave the amount of mechanical work wasted by conversion into heat. Breaking the compression curve, cooling the air, and commencing compression again with a reduced volume caused the actual compression curve to have two distinct parts, the curve showing the second stage compression falling much more nearly to the isothermal. The economy was given by (area contained by the compression line if completed in one stage) — (area contained by actual compression line). The economy due to multi-stage compression increased as the pressure ratio increased.

Visit of Automobile Engineers to the United States.—Arrangements have been made for a joint visit of the Institution of Automobile Engineers and the Society of Motor Manufacturers to visit the United States this spring. The party will leave London on May 17th, and proceed to New York, Pittsburg, Indianapolis, Detroit, Cleveland, Buffalo, Providence, Bridgeport, Newhaven, and Hartford. Particulars of the trip may be obtained from the secretary of the Institution of Automobile Engineers, 13, Queen Anne's Gate, S.W.

WORM GEAR FOR MOTOR-CARS.

An interesting paper on "Worm Gear" was recently read by Mr. F. W. Lanchester before the Institution of Automobile Engineers. Power-transmitting worm gear for motor cars required, he said, to comply with two main conditions: (1) it must give an efficiency comparable, if not equal or superior, to the efficiency of the alternative types of gear, *i.e.*, bevel or chain; and (2) it must be of approximately similar weight and size to a bevel gear of equal horse-power capacity. It was unnecessary to mention silence as a third condition, since this was the direction in which worm gear was notoriously beyond reproach, while on the score of efficiency modern worm gear was well able to hold its own. Lanchester worm gear, tested at the National Physical Laboratory, showed efficiencies varying from 95 per cent. to 97 per cent. On the score of weight and compactness the Lanchester worm gear did not compare unfavourably with bevel gear, and the size and weight of a rear axle for a given duty was approximately the same for both types of gear. Apart from considerations of the load carried, the efficiency of worm gear or screw gear was a function of the angle made by the teeth. Neglecting journal and thrust friction, or including such bearing friction in the total reckoning of tooth friction, the best efficiency was obtained when the worm tooth angle was 45° *minus* half the effective angle of friction. The maximum load that could be transmitted by any gear pair depended mainly on the type of worm or screw gear employed, and on what tooth pressure the gear would stand without expelling the lubricant from between the engaged surfaces. In some cases the limit was not the oil film, but rather the hardness of the materials of which worm and wheel were constructed.

The main factor in determining the size of the worm gear for motor vehicles was, he said, the torque on the driving axle. Now if it were proposed to propel any given vehicle with an engine of specified horse-power that power might be obtained by large cylinders and slow revolution speed, or smaller cylinders with a higher revolution speed; it was evident, therefore, that a ready means was required to compare the power transmission capacity of worm gears of given centres, under conditions of constant driven torque and variable-speed reduction ratio. It might be pointed out that in certain cases, especially where noise was unimportant, a gear might be used between the motor and worm shafts in place of the direct drive in order to accommodate a worm standard that might otherwise be unsuitable. The selection of a suitable gear depended on four factors—the weight of the vehicle and the diameter of the driving wheels on the one hand, and the centres of the gears and the torque curve on the other. It was thus quite a simple matter to specify the proportions of the worm gear required for any given duty.

In the design of different types of gearing, whether worm or spur gear, the important factors differed considerably according to the type of gear employed, and even according to the ratios required. Thus, in spur gearing the strength of the teeth was a very important factor; in power-transmitting worm gears the strength of the teeth need rarely, if ever, be considered, for designs which fulfilled the other necessary conditions were usually found to possess ample strength. Again, in spur gearing the pitch diameters, or, in the case of involute gears, the rolling circles, required to be selected exactly in the ratio of the transmission, and no departure was permissible; in worm or screw gear, on the other hand, no such rigid condition existed, and the angle of the gear teeth might be selected to accommodate any diameters required. For given gear centres the gear ratio was a function of two variables—namely, the size ratio of the blanks and the tooth angle—whereas in the ordinary spur gear the one variable alone determined the gear ratio.

The author had for many years expressed the force transmitted by the teeth as a pressure per square inch on the projected area of the worm wheel teeth. On this basis worm gear cut according to his system would carry easily one ton per square inch, and was good for an overload of two or three times that amount—in fact, a load of two tons per square inch might be regarded as a safe load, inasmuch as the gears would run satisfactorily with such a load for an

indefinite period. Taking a car and passengers weighing two tons gross on a one in 12 gradient, there was roughly a tractive resistance with allowance for road resistance of 0·2 of a ton, which represented on the worm teeth 0·8 tons on a projected area of approximately half an inch, or 1·6 ton to the inch. The gear would work quite satisfactorily and would show no signs of distress under these conditions.

The most important direction in which it was desirable to test worm gear was to determine its efficiency under various conditions of load and speed. Where the efficiency of any piece of mechanism was high, such tests, to be of any real service, must be carried out with a very high degree of accuracy. It might be said that unless the loss of power could be determined to within about 5 per cent., the method was unsatisfactory. Thus, taking 96 per cent. as a good average worm gear efficiency, the loss of power was 4 per cent., and the determination should be within an error of one-fifth of 1 per cent. This was the degree of accuracy obtained as certified by the Director of the National Physical Laboratory by the new Daimler-Lanchester testing machine. In principle the new machine was an instrument for the direct comparative measurement of two torques acting about axes at right angles, or more generally about axes making any angle with each other, but unsuited to cases where the torque axes approached the parallel. Many facts of considerable importance both to the designer and to the user had been elucidated by recent tests with the new method. It appeared that at the best the parallel worm could scarcely reach the efficiencies shown to be regular with the Lanchester gear; at the worst the efficiency of the parallel gear fell 3 or 4 per cent. lower, particularly in the case of heavy loads. It would appear that the oil film began to break down in the case of the parallel worm at loads which the Lanchester gear sustained without loss of efficiency. The loss of efficiency at reduced speeds was far less than had been previously supposed; at the lowest useful motor-car speeds it rarely fell much below 94 per cent., and it was quite exceptional to record efficiencies below 93 per cent. Great variations in efficiency were due to differences in the lubricant employed. In general, mineral oils were much inferior to animal or vegetable oils. The viscosity of the oil was little or no guide in the selection of an oil for the purpose in question; and the efficiency might be lowered by the presence of too much lubricant in the gear box. The best efficiencies were obtained with a certain perceptible tooth clearance, and the best clearance in an ordinary motor-car gear appeared to be about $\frac{1}{64}$in.

THE FUTURE OF GAS AND OIL ENGINES.

SPEAKING at the recent annual meeting of the shareholders of the National Gas Engine Company at Ashton, Mr. Dugald Clerk, one of the directors, said gas-producing plant had not kept pace with the gas engine, and as soon as a satisfactory gas-producer plant was made gas would make its way in the marine world. The Government, he added, were quite alive to the possibilities of the internal-combustion engine, and it was possible that they would soon be building at Ashton engines for battle-ships. Many people predicted a great future for oil, but it had not the enormous future which people believed. Every year 1,100,000,000 tons of coal were brought to the surface, and only 45,000,000 tons of oil. If all the oil raised were applied for power purposes they would only have about a quarter of the fuel that was necessary. On the sea at present they had 26,000,000 horse-power, and they could never supply those engines with oil because supplies had first to be used for petrol, lighting, and lubricating. Oil would have its field, but the greatest field for the internal-combustion engine was for the engine which used coal in its different forms.

The Iron and Steel Institute.— The annual meeting will be held at the Institution of Mechanical Engineers, Storey's Gate, Westminster, on Thursday and Friday, May 1st and 2nd. The Bessemer Gold Medal will be awarded to Mr. Adolphe Greiner, general director of the Société Cockerill, Seraing. The autumn meeting will be held at Brussels.

SPONTANEOUS COMBUSTION OF COAL.

IN the course of a paper recently read before the Manchester District Institution of Gas Engineers, Mr. Kendrick mentioned that three serious fires had taken place in four years in stacks of coal at his works at Stretford, in addition to many cases of overheating, and endeavoured to explain their cause. The coal was stored in three buildings. No. 1 store held 1,800 tons, and was an old retort house partly roofed, with and partly without louvres. No. 2 store held 1,400 tons and had no louvre. No. 3 held 800 tons, and had a roof of corrugated iron. In the first two coal was delivered by conveyers. In No. 3 it was hand-stacked, 14ft. high. In the other stores it was piled in pyramids 24ft. and 20ft. high, the top of the cones being 8ft. across. No 1 shed had given most trouble. The finest slack was usually sent direct to the retorts, but much fine stuff still got into the store and filled the middle part of the piles, and to this dust and small coal the fire trouble was due.

As a result of what was observed, after each boat had been discharged, the fine dust was dug out and spread over the heap, and pipes were put in at intervals to enable the interior of the pile to be watched. Three years of immunity led to laxity, and the small stuff had not been fully dug out, and a fourth fire occurred. It was again the small coal which heated, but was not the immediate cause. Some old screened coal was buried under the new coal, and the store was filled in about six weeks to its utmost capacity. On emptying the shed, the rough coal under the slack was quite carbonised and fire was creeping under the slack. Apparently air had reached the new coal through the old tongue of open rough coal. The temperature in the tubes rose slowly to 90°, then quickly to 110°, with a quick jump to 300°, and it required a week to reach the fire, which had then spread considerably. As this coal was stored in the hot month of May, 1912, and was stacked quickly and was dustier than usual, these causes appear to have been active in producing fires. The numerous fires of that year were attributed by colliery agents to the fact that after the strike, coal was much crushed at the face, and was very small, and it was not clean, being hurried away quickly for use, and more probably fresher coal than usual was stacked. Freshly-wrought coal was more prone to heat, especially if fine. Coal as received was warmer than the atmosphere, as much as 2° to 12° in summer, and 4° to 20° in winter. Since a pit might have a temperature of 90°, coal must start from the pit fairly warm, and if stacked too soon, too high, or in too large mass, it was prone to heat. Also, coal mined first after the strike would be damper than usual, and dampness seemed to engender fire.

Coals absorbed from one to three times their volume of oxygen, and this produced heat, and if it could occur in a thick mass the heat accumulated. Stacking in cone shape from a conveyer caused the fines to accumulate at the apex, and these were apt to fire. This system of storage was thus to be regarded with suspicion. Coal owners suggested 11ft. to 15ft. as the height of coal stacks, or a mean of 13ft. Gas-works practice was to stack 10ft. to 30ft. Since coal under cover cooled less slowly, it should be stored in less depths than when out of doors, whereas the reverse was the usual practice. The question of ventilation was a disputed one. Ventilate freely and carry off the heat was advocated by some, while others said keep out all air and no heat could be generated. If this was so it would be quite safe to store in closed bunkers, exhausting the air at the top and admitting CO_2 at the base to fill the voids between the coal. In practice it appeared that coal would be reached by air enough to make it become hot. Therefore ample air should be supplied to carry off the heat, for the oxidation would be less if the coal was cold. Yet in mines ample ventilation to remove gas had caused heating in the gob, and the checking of the air current had stopped the heating.

If a heap fired, very much water was needed to quench it, for water set up air currents to fan the fires. At Stretford they treated affected coal with strong ammoniacal liquor and only put water on unaffected coal. The summing up was that coal from different seams should not be mixed, nor should coal of different classes. Fine slacks should not be stacked at all, nor damp coal under cover. Large heaps were the more dangerous. Lumps, nuts and fines should be well

mixed in stacking. Heights should be limited to 20ft. in the open, and 16ft. under cover. External sources of heat, leaking roofs, &c., should be avoided. Temperature records should be kept of coal as received and in stock, and if the heat rose to 90° or 100° the top layers should be removed and carefully watched. A fired heap should not be disturbed by pushing in bars while water should not be applied to a fire, but ammoniacal liquor. Heated coal should be removed and used promptly.

THE COOLING OF HIGH-SPEED ELECTRIC GENERATORS.

It is well known that with large and high-speed electric generators, air cooling is often resorted to in order to prevent injury from over-heating, and to keep down ratios of weight to output. Since the air in the vicinity of a power plant is not particularly clean, much coal and metal dust is often blown into the machine windings, causing danger of short-circuits and making the cleaning of the machine a frequent necessity. In power plants it is now usual to equip them with air filters for the cooling air of the generators. These filters generally consist of strong cloth (specially woven for the purpose) which is stretched over frames of wood or iron. These frames are set in a zig-zag fashion after the manner usually adopted in air-filter arrangements to allow sufficient surface for the passage of the air, but, at best, are hard to keep clean and necessitate duplicate units or use of unfiltered air during cleaning.

In a recent issue of "The Engineering News" Mr. O. E. Trautmann gives a description of a new type of filter designed by Mr. Bollinger, the former power superintendent of the City of Charlottenburg, Germany, whose advantages lie in compactness and ease of cleaning. This filter consists of single sections which are now manufactured in three standard sizes, each for 100,000, 140,000 and 175,000 cub. ft. of air per hour. These sections are built up to meet the capacity required and to suit the space available. Fig. 1 shows the dimensions for two sections each of 140,000 cub. ft., and is fairly typical of other capacities, except as to size. The filtering elements are set in a housing of angles and sheet iron, comprising three compartments: (1) the air inlet, "A"; (2) the frame box, "B"; and (3) the air outlet, "C." In the frame box are placed 20 to 25 frames, of small iron T-bars; each frame is equipped with cotton ropes strung very close to each other, giving but a small air passage between. Details of the method of attaching these ropes to the T-irons are shown in Fig. 2. These frames are put into position so that the spaces of the upper frame between the ropes are always vertically over the ropes of the next lower one, that is, staggered as shown in Fig. 3, forcing the air to change its direction of flow repeatedly while passing through. A slot for a sliding damper is provided so that it is possible to shut one section off at a time for cleaning. After shutting a section off by this damper the cover of the frame box is removed, when each rope frame can be withdrawn and cleaned. It is generally the practice to use two sections as shown in Fig. 1, and a spare set of rope frames. Then one section has to do all the filtering during a minimum time only—the interval required in which to remove the clogged frames and to insert the clean ones in their place. This requires but a few minutes and throws extra load on the remaining frames for such a short time as to be practically negligible. The air inlet is covered with a wire-mesh screen for protection, while the air outlet or outlets are generally connected together into some sort of chamber from which ducts are run to desired points.

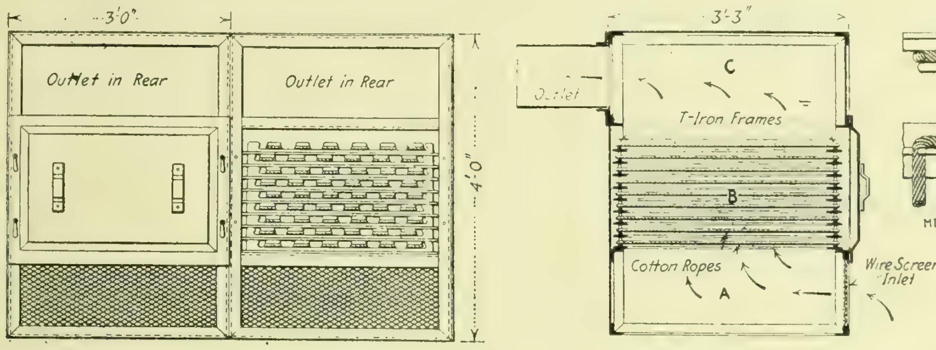
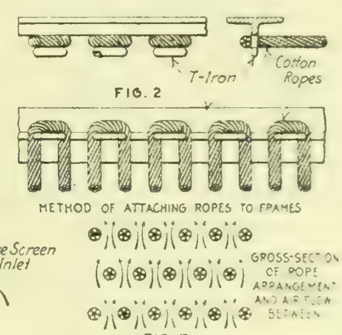


FIG. 1.—ELEVATIONS OF A 140,000 CUB. FT. AIR FILTER, BOLLINGER COTTON ROPE TYPE.



FIGS. 2 AND 3.—ATTACHMENT OF COTTON ROPES IN BOLLINGER AIR FILTER AND DIAGRAMMATIC CROSS-SECTION.

ELECTRIC CONDUITS.

In the course of a paper on "Electrical Installations in Metal Conduit, with Special Reference to Earthing," read before the Junior Institution of Engineers, Mr. Frederic H. Taylor said that, in spite of fire insurance rules, fire surveyors, institute wiring rules, and other precautions which had been devised for the safety of the consumer, a large amount of wiring work was still carried out by means of a slip socket tube, consisting of light steel enamelled conduit having an open seam. The use of this tube was often actually dangerous, and it ought not to be permitted. The rules of the Institution of Electrical Engineers wisely permitted the use of this conduit only in dry positions, and then it must be earthed unless consisting of isolated single lengths. Trouble was generally caused by the difficulty of satisfactorily earthing the tube; a good deal could be done to improve matters in this respect if contractors would use galvanised slip socket instead of enamelled conduit. Among the misuses to which slip socket conduit was frequently put was burying it under plaster work, a practice that was rightly condemned by insurance offices. In this case moisture entered the conduit as the plaster work was laid, and it had no opportunity to get out. The tube possessed one possible advantage in that, as the wireman had no need to twist the tube into various fittings such as sockets, bends, &c., he had at least an opportunity given him to avoid twisting the wires in the tube.

In screwed pipe work three patterns of tube were generally used, these being the brazed, the welded, and the solid drawn or seamless tube. In the author's opinion the solid drawn was the most satisfactory to use, and it was also the most expensive. Solid drawn conduit lent itself to bending well, and it was free from possible defects in the way of internal burrs or other roughnesses. It was sometimes urged that in a screwed pipe system there was every chance of trouble from condensation. He had found that condensation was more fanciful than real, particularly if proper care and skill were used in choosing the right position in which to run the conduit. Often conduit was put in most absurd positions, where condensation was sure to result. Points which tended to efficiency were straight runs, avoidance of elbows and tees, liberal use of boxes for drawing through, ample size of tube, metal bushing pieces to all ends of tube, and an insistence that every piece of pipe on the job should be fitted and permanently fixed in position before any wire was drawn in.

The earthing of all pipe and other metal work was now universally recommended by various authorities. Properly a pipe should be earthed by means of a solid clip which made contact with as much as possible of the circumference of the pipe. This should be provided with a removable socket into which was sweated the earthing wire, which should never be less than 1/14 s.w.g. The other end of this wire was supposed to be taken to a live water main and there attached to

it in a similar manner to that already prescribed for its other end. In practice wiring contractors and their wiremen, electric supply companies, and also municipal supply authorities seemed to be forgetful of the proper means and need of efficient earthing, in spite of the elaborate rules and regulations thoughtfully provided by them for the public benefit.

THE APPLICATION OF TURBINES TO MINES.

THIS subject was dealt with in a paper read at a recent meeting of the Association of Birmingham Students of the Institute of Civil Engineers, by Messrs. C. H. Bailey and R. H. N. Vaudrey. In mining engineering the usefulness of turbines was, they said, being recognised in no small degree. Every day more mines were being equipped with turbines, mostly of the mixed pressure type. But even now their usefulness might be increased to a very large extent. When steam was used for the winding engines, the turbine would almost certainly be an economical factor for a large colliery plant, as there would be a very large quantity of steam which in all probability would be exhausted directly from the winding engines at a pressure of several pounds above atmospheric pressure. The economy resulting from the use of turbines was summarised as follows: Above 200 kw. the steam turbine was more efficient than the reciprocating engine. The first cost of small turbines was about the same as for reciprocating engines. But for larger units the prime cost was only about half the cost of the reciprocating engine set, including condensing plant. The steam consumption of a turbine of 2,000 kw. output may be about 15 per cent. better than a quadruple expansion engine, and the maintenance was considerably less. The buildings and foundations necessary for a turbine were also very much less costly than for the corresponding reciprocating plant. Depreciation and repairs for a turbine were also comparatively less.

BRITTLE CASTINGS.

AT a meeting of the Scottish Branch of the British Foundrymen's Association, held at Glasgow on Saturday last, a paper was read by Dr. C. H. Desch, on "Sulphur and Oxygen in Iron and Steel. The subject was considered from the chemical point of view, and the presence of sulphur in iron was traced to the conditions favouring its reduction from the raw materials in the blastfurnace. This impurity was shown to be most deleterious to the metal when it existed in the form of iron sulphide, which, having a lower melting point than the iron, was able to encase the crystals in a most brittle meshwork, thus making the iron useless when sufficient sulphur was present. With the addition of manganese, however, a new compound occurred—namely, a double sulphide of iron and manganese, and this was much less harmful owing to its higher melting point. This property entailed its separation from the metal before the iron solidified, and with careful melting the sulphur could be largely eliminated, thus producing stronger iron. Too high a temperature was stated to be capable of melting this sulphide, and so entangling the harmful constituent which otherwise escaped from a colder, thick-running metal. In the case of steel too much of this sulphide produced brittleness, even although it was proved to be plastic and capable of extension along with the metal during rolling. The effect of oxygen was to produce oxides in steel, it being very infrequently met with in iron. These inclusions found in burnt metal were said to be capable of largely increasing the tendency of the metal to corrode rapidly, and similar defects were apt to be set up by welding. Silicates were also formed, and either alone or in conjunction with the sulphides produced sources of weakness in the metals containing them.

A Sawdust Explosion.—Particulars are given in "Engineering News" of a sawdust explosion which occurred in the box factory of the H. H. Sheip Manufacturing Company, of Philadelphia, Penn., on February 5th, injuring six of the employés, one fatally. A bolt falling among the cutters on a sawdust grinding machine is reported to have caused a shower of sparks that served to ignite the particles of sawdust in the air. Explosions of a similar nature are of common occurrence in coal mining, and have occurred also in flour mills and other industries producing inflammable dust.

INDUSTRIAL AND TRADE NOTES.

Wireless Stations in Wales.—The Marconi Company have made arrangements to erect a station for receiving wireless messages at Towyn, Merionethshire. This station, which will be connected with another at Carnarvon, will be erected on Escuan Hill. situated behind the town, 1,300ft. above sea level. It will be in direct communication with New York.

American Iron Ore Production.—According to preliminary figures published by the United States Geological Survey the total quantity of iron ore mined in the United States during 1912 was between 54,500,000 and 57,500,000 gross tons, an increase of 25 to 32 per cent. in comparison with the figures for 1911. It is thought possible that later statistics may show that the output of 1910, 56,889,734 tons, the highest attained, has been slightly exceeded.

Postal Railway Tubes for London.—The proposed scheme of "tube railways" in London for the conveyance of mails and parcels is, we understand, receiving favourable consideration. According to the original recommendations the proposed route would be just over six miles in length, beginning at the Whitechapel District Post Office and ending at Paddington. Liverpool Street, the General Post Office, the West Central, and the Western District offices will be connected by means of the tube. The estimated cost of the scheme is a little over half a million pounds.

The Utilisation of Exhaust Steam.—There has recently been installed at the iron and steel works of Messrs. Monks, Hall & Co., Ltd., at Warrington, two 750 kw. direct-current mixed-pressure turbo-generators of the Rateau type, with surface condensers. All the exhaust steam from the works engines is collected into one main and is then supplied to the turbines at a pressure of 16lbs. absolute. The power generated, representing from 1,000 h.p. to 1,300 h.p. will be utilised in driving the auxiliary plant and in illuminating and operating one of the mills.

Iron Trade Combination Breaks Down.—The proposed agreement between ironfounders and distributors of their products for the regulation of profits and prices by means of rebates has, we understand, fallen through. Certain provisional arrangements will be given effect to until June 30th next, when the whole arrangement comes to an end. This was the most comprehensive effort at combination ever attempted between manufacturers and distributors in the iron trade, and the protracted negotiations, originating in Glasgow and continued in London, have throughout been attended by much difficulty.

Subsidised Motor Lorries.—The War Office announces that as the result of the trials of subsidy type vehicles held in January, the War Department certificate enabling vehicles built entirely to the same design, to be subsidised under provisions of the subsidy scheme for petrol driven motor lorries, has been awarded to J. & E. Hall, Ltd., London and Dartford, and J. I. Thornycroft & Co., Ltd., London and Basingstoke. Both of the certificated vehicles were entered in Class A to carry a load of three tons. Certificates for both Class A and Class B vehicles have already been granted to Leyland Motors, Ltd., Leyland.

The Coal Production of Canada.—According to a bulletin just published by the Department of Mines, it appears that 11,323,338 short tons were mined in 1911, compared with 12,909,155 tons in 1910, a falling off of about 12 per cent., due to labour troubles. The approximate selling value of the coal at the mines in 1911 was $2.34 per ton, compared with an average of $2.39 per ton in 1910. Of the total production, 75·6 per cent. was sold for consumption in Canada, 9·4 per cent. for export to the United States, and 2·5 per cent. for export to other countries, with 3·4 per cent. used by colliery operators making coke, and 9·19 per cent. used for colliery purposes and by workmen.

Industrial Alcohol for Fuel.—Industrial alcohol can, it is stated, be produced from the refuse of the sugar factories at Demerara at 4d. per gall. In addition to sugar, maize is said to be rich in carbohydrates, which yield the highest percentage of crude alcohol. Maize contains 70 per cent. of carbohydrates. Engines constructed for kerosene can usually work with alcohol without any adaptation, and the storage of alcohol is much less dangerous than that of petrol. Alcohol, however, has not the same value per horse-power as petrol, 1·8 times as much being required, but in places where maize or sugar is plentiful it could be produced at so much lower cost as to permit of its employment.

The Largest Oil-carrying Steamer.—There was launched from the Wallsend shipyard of Messrs. Swan, Hunter, & Wigham Richardson, Ltd., on the 22nd inst, the largest oil carrying steamer

in the world. The vessel named the "San Fraterno" has been constructed to the order of the Eagle Transport Company. She is 510ft. in length, 66ft. 6in. in breadth, and her depth is 34ft. 3in. She will have a deadweight capacity of 15,590 tons, which means that the vessel will be able to carry several million gallons of oil. She will burn oil fuel. The "San Fraterno" is the first of nine or ten similar vessels building, at different shipyards, there being a sister ship at present under construction in the same yard at Wallsend.

The New Shipyard Agreement.—The new national working agreement between the Shipbuilding Employers' Federation and the Shipyard Trade Unions was signed at a conference held on the 18th inst. at Edinburgh, between the Executive Board of the Federation and the Standing Committee of the Unions. The Standing Committee reported that the unions had decided in favour of the new agreement by 7,383 votes to 1,919—a majority of 5,464 in favour—and that therefore they were authorised to accept and sign it on behalf of the different societies. The new agreement will hold good for three years, and will be terminable then on six months' notice by either side. That is, it will rule in the first place for 3½ years, as notice of its termination can be given only on the conclusion of the three years. In this respect it resembles exactly the agreement of March, 1909.

Shipyard Wages.—It is understood that an application is being made by the Standing Committee of the shipyard trade unions for a general advance of wages. The claim is for an increase of 5 per cent. on piecework and ¼d. per hour, or 1s. per week, on time rates. This is the "fluctuation" stipulated in the new national agreement signed a few days ago by the employers and the men, and as it is not being asked locally but nationally the application will be dealt with in a grand conference direct as soon as arrangements for this can be made. In accordance with the agreement, a preliminary conference will first be held—within 12 days of the application—to be followed later by a conference at which the application will be fully considered. The last change of wages was made six months ago when a general advance of 5 per cent. was granted. The period covered by that advance has now expired, so that another application is in order.

Trials of an Oil-engined Coaster.—Trials were run on the Firth of Clyde on Friday last by the oil-engined coasting vessel "Isleford," which has been built by the Ardrossan Shipbuilding Company for Messrs. Mann, Macneal, & Co., Glasgow. The "Isleford," which is fitted with a Bolinder's four-cylinder oil engine, developing 350 b.h.p. at about 325 revs. per minute, is 149ft. in length, 25ft. 6in. in breadth, 11ft. in depth, and of 780 tons loaded displacement. The engines can be got under way from cold in from 20 to 25 minutes, and the operation of the reversing gear is on the same principle as in smaller engines of the type. The installation of Bolinder's machinery, which is the most powerful yet fitted on any vessel, has been supplied by Messrs. Douglas, Primrose, & Co., engineers, Glasgow. On the trials the vessel ran continuously for about five hours under normal conditions, and fully loaded. On the measured mile she attained a maximum speed of 9·67 knots and a mean speed of 8·9 knots, the engine running at a uniform speed of 218 revs. per minute. The speed stipulated in the contract was 8½ knots. The fuel used was Scotch shale oil, and the consumption was at the rate of 18 gallons per hour.

Panama Canal and its Effect on Trade.—Addressing the Royal Statistical Society on the 18th inst., on "The Panama Canal and Competition for Trade in Latin America, the Orient, and Australasia," Prof. Lincoln Hutchinson, of the University of California, said the changes in trade routes, while of immense significance in certain countries, would by no means be as fundamental as those wrought by the opening of the Suez Canal. To many of the most important parts of the globe the new canal would merely open an alternative route; to several others it would offer no advantages whatever and their trade would cling to its present routes. The three chief competitors were the United Kingdom, the United States, and Germany, and each possessed certain distinct advantages and disadvantages in the trade. Britain's position was particularly strong in that she was in a certain sense already in possession of the greater portion of the field. Germany and the United States were the attacking parties. Britain's long pre-eminence in the markets, the wide spread knowledge of the excellence of British goods—those and other things all operated strongly in her favour. On the other hand, that very strength had led to certain weaknesses: conservatism of method, both in manufacture and marketing, a lack of adaptability to peculiarities of demand, and a certain over-confidence in the inevitability of continued success. On the whole, in the trade with the "Canal countries," the German and American attack on the market had met with some success. Great Britain, although still holding nearly 50 per cent. of the trade, had declined, while the United States and Germany had both increased their share. The fact that the United States, in spite of serious handicaps, had more than held its own in the competition pointed to an important advance once the Panama Canal was in full operation; for that country would unquestionably reap greater benefits in increased accessibility of the markets in question than Great Britain, Germany, or any other European country.

The Ghent International Exhibition.—To build an hotel to hold 100 guests on purpose to prepare for the rush of visitors to the Ghent International Exhibition, and then to pull half of it down again when the Exhibition closes, is one of the striking pieces of enterprise which the municipal authorities of the town have undertaken. The hotel is in no way a temporary structure, but brick built throughout, and the remaining half will continue under the management of the town as a station hotel at the new railway station on the main line from Ostend to Brussels. The station, the Gare St. Pierre, may almost be described as an Exhibition enterprise, too, for it is just on the edge of the ground and the work has been specially put forward so that it may be ready for the exhibition traffic. There is a general belief that directly an international exhibition is opened in a town hotel prices jump to famine rates, and that visitors have to pay most exorbitant sums for the bare necessaries of life. This may have been true at one time, but it is not so to-day, for it is greatly to the interest of the exhibition authorities to see that prices are kept as low as possible, and the lengths to which the Ghent Exhibition authorities have gone in building this special hotel to provide rooms at a fixed and reasonable price for visitors, are typical of this modern spirit. But apart from the erection of this hotel a "bureau de logement" has been formed to inspect and classify all the private apartments available. The price of these, 3 frs., 5 frs., 6 frs., 10 frs., or 15 frs. for the night and breakfast is also fixed by the bureau, so it is obvious that the keepers of hotels and boarding houses will not be able to raise their charges to famine rates in the face of this competition. This bureau, which is not a business concern and has no financial interest in the work, will have offices at both the railway stations and at the exhibition, and on applying there visitors will be given the addresses of vacant rooms at the price selected. As these will all have been inspected and priced by the committee there will be little trouble in finding suitable accommodation. In order to provide for the visit to the exhibition of large parties from workmen's clubs and institutes the bureau has also hired a number of large halls, and is fitting them up with the assistance of the military authorities as dormitories where as many as 100 or 150 men can be lodged at a time. The charge for these dormitories will only be sufficient to cover the expenses, but arrangements will have to be made beforehand with the Bureau de Logement. Yet another fact which will prevent any great rise in prices in Ghent is the nearness of Brussels, Bruges and Ostend. Bruges can be reached from Ghent by train in 35 minutes; Brussels in 50 minutes, and Ostend in 60 minutes, journeys which are of no greater inconvenience than those taken by many suburban dwellers every morning.

METAL QUOTATIONS.

TUESDAY, FEBRUARY 25TH.

Aluminium ingot	93/-	per cwt.
„ wire, according to sizes, &c. ......from	112/-	„
„ sheets „ „	120/-	„
Antimony ......£36/-/- to	£37/-/-	per ton.
Brass, rolled	8⅝d.	per lb.
„ tubes (brazed)	10⅝d.	„
„ „ (solid drawn)	9¼d.	„
„ „ wire	8½d.	„
Copper, Standard	£64/-/-	per ton.
Iron, Cleveland	60/7½	„
„ Scotch	66/7½	„
Lead, English	£16/17/6	„
„ Foreign (soft)	£16/10/-	„
Mica (in original cases), small	6d. to 3/-	per lb.
„ „ „ medium	3/6 to 6/-	„
„ „ „ large	7/6 to 11/-	„
Quicksilver	£7/15/-	per bottle.
Silver	27 15/16d.	per oz.
Spelter	£25/-/-	per ton.
Tin, block	£214/-/-	„
Tin plates	14/3	„
Zinc sheets (Silesian)	£28/17/6	„
„ (Stettin; Vieille Montagne)	£28/17/6	„

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Apparatus for preventing over speeding and over winding of mine cages. Wilson & Reah. 132.
Internal combustion engines. Pitts. 2335.
Rotary valves for internal combustion engines. Mayet, Gibaud, and Joubier. 2487.
Apparatus for preventing over winding at collieries. Ashton. 2657.
Starting gear for internal combustion engines. Leitner. 2746.
Boring bars and boring heads. Lumsden & Blake. 2748.
Transmission of power from a prime mover to a load. Arter and Arter. 2818.
Rolling mills. Dixon & Taylor. 2860.
Silencing and withdrawing the exhaust gases from cylinders of internal-combustion engines. Mansfield. 2921.
Centrifugal pumps. Barbezat. 2926.
Carburetters for internal combustion engines. Ball & Ball. 2931.
Dirigible airship. Schlegelmilch. 2954.
Valves of internal combustion engines. Ricardo & Hetherington. 3024.
Vertically-ascending flying machines. Schultze. 3110.
Furnaces. Smallwood. 3152.
Fluid meters. Murray & Gibb. 3165.
Liquid fuel burners and liquid fuel vaporising apparatus. Maardt. 3401.
Internal combustion engines working with coke oven and other gases. Clerk, and National Gas Engine Company. 3420.
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The Mechanical Engineer

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WILLIAM H. FOWLER
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The Corrosion of Pipes in Circulating Hot-water Systems.

THE apparently whimsical effects of corrosion in circulating hot-water pipes used for the heating of buildings has given rise to a good deal of discussion at one time or another and led to considerable difference of opinion as to the relative merits of iron and steel pipes used in such service. The corrosion usually takes the form of local and somewhat severe pittings, which rapidly eat their way through a pipe, and by disorganising the service cause a good deal of trouble and annoyance. The fact that such corrosion develops in some cases and not in others when working with the same water and under apparently identical conditions of pressure and temperature has made the matter more puzzling. The leading authorities now seem agreed that the corrosion is initiated by mill scale and rust, and that its continuous action depends not so much on whether the pipe is of iron or steel, provided its composition is reasonably uniform (as steel used for welded pipes necessarily must be), as upon the presence of carbonic acid and oxygen of the air in solution, and that the removal of these gases greatly lessens the tendency to corrosion. The question is one of importance, and assumes serious magnitude when large buildings, such as are now so common, are heated by circulating hot-water systems. A recent investigation undertaken by Mr. F. N. Speller, of the National Tube Company, Pittsburg, and recorded in "The Engineering News," shows pretty conclusively that the question is largely under control, and that the corrosive effects observed depend to a great extent on the circulating system itself,* which is usually arranged either on the under-feed or over-feed systems. In the under-feed system the hot water supply from the boiler is delivered into a horizontal main in the basement, from which, without going into details, a series of vertical upcasts rise in the various sections of the building heated, which at their upper

* For further details see "The Mechanical Engineer," page [illegible] ante.

extremities are coupled to downcomers united to a collecting return main in the basement. In the over-feed system the hot water supply is conducted through an upcast pipe to a horizontal main above the level of the highest point of the system. From this main the hot water flows through a series of downcomers through the various sections of the building to a collecting return main in the basement as in the other case. The under-feed system, it will be seen, is characterised by a number of pairs of independent risers and downcomers which are rarely vented at the top, and consequently water is always saturated with air when the system is in continuous use, and its design is such that it would be difficult, if not impracticable, to vent it so as to remove any dissolved air before the water is used. On the other hand, the over-feed system readily lends itself to the separation of air by connecting the vertical supply main to an open tank at the top, from which the horizontal distributing main is fed. The difference mechanically between the two arrangements is not great, but from the investigations conducted by Mr. Speller into a number of heating systems, it seems to account almost entirely for the differences in corrosive effects observed in practice, and for this reason is to be recommended to the notice of engineers and architects responsible for the heating arrangements of large buildings.

Sawdust as a Fire Extinguisher.

SAWDUST scarcely suggests itself as a suitable material for extinguishing fires, but from the account of some experiments by Mr. E. A. Barrier, a Boston engineer, embodied in a report made under the direction of the Associated Factory Mutual Fire Insurance Companies, it would appear that it possesses some special merits when dealing with small outbreaks of liquid combustibles, such as lacquer and petrol, which are usually difficult to extinguish by ordinary means. Sand is generally looked upon as the best substance to use in such cases when it can be applied promptly, but the tests showed sawdust to be greatly superior. The tests were made with flat, rectangular tanks in which a quantity of combustible was poured and ignited, and allowed to burn for about a minute before efforts were made to extinguish the flames by spreading a few shovelfuls of sawdust on the surface of the liquid. It made little difference to the effectiveness of the sawdust as an extinguisher whether it was damp or dry, and whether it was the product of hard or soft woods. A number of commercial lacquers, as well as samples of petrol, were tested in this way, and in all cases the flames were extinguished in from 25 secs. to 50 secs., and with a very thin sprinkling of sawdust. When efforts were made to effect the results with sand a much larger quantity was required, and the process of extinction was much slower. The efficiency of the sawdust seems to be due to its blanketing action in floating for a time on the surface of the liquid and excluding air, and naturally its efficiency is greater on viscous liquids than on thin ones, since it floats more readily on the former than the latter. The amount of moisture contained in the sawdust was apparently not a factor, since sawdust which was dried was just as efficient. Sand appears to be less satisfactory, because it sinks through the liquid and has not the same blanketing action. It was found, further that the efficiency of sawdust as an extinguisher was greatly increased by mixing it with sodium bicarbonate—10lbs. to a bushel of sawdust—since this material when heated liberates carbonic acid. Sawdust itself, however, contrary to the general impression, is not easily ignited, and burns without flame, while it would be difficult, if not impossible, to ignite sawdust mixed with bicarbonate with a carelessly thrown match. Of course, it is not suggested that sawdust is a material to use when once a conflagration has got hold, but the tests clearly show that in many works where lacquer and similar inflammable substances are liable from some accidental circumstance to ignition, either in tanks or from leakage on to a floor, a supply of sawdust, especially if it is bicarbonated, is a most convenient precaution for stamping out the initial fires from which big ones spring.

Sir William White.

THE death of Sir William White, the great naval architect, has come with startling suddenness. He was taken with a sudden seizure in his office and conveyed to Westminster Hospital, where he died on Thursday last at the age of sixty-eight. Like many other leading Admiralty men, Sir William sprang from the ranks entirely by his own exertions and abilities. Born at Devonport on February 2nd, 1845, he entered the Royal Dockyard at that town as a shipwright apprentice at the age of sixteen, and at the Dockyard School which he attended gave early proof of the scientific and mathematical knowledge on which his fame subsequently was built. Winning an Admiralty scholarship at the dockyard he entered, at the age of nineteen, the School of Naval Architecture at South Kensington, where he studied for three years, and gave evidence of his brilliance by taking first place at each annual examination, and graduating with a first class diploma. In 1867 he entered the designing and constructive department of the Admiralty, then under the head of Sir Edward Reed, who promptly recognised his abilities by assigning him responsible work. At that time the leading designs of battle-ship were represented by vessels of "Devastation" and "Inflexible" citadel class of ships, and difficulty was experienced in carrying the armour of adequate thickness to withstand even the attacks of the low-velocity projectiles from the 20-ton muzzle-loaders of the period. The disaster to the "Captain," which foundered on her trial trip, led to a Parliamentary enquiry, and the appointment of White and the late William John to make a mathematical study of ship stability. Following this his rise in the Service was rapid, and in 1883, at the age of thirty-eight, he became chief constructor. Coincident with this post he retained his position as Lecturer on Naval Architecture at South Kensington, and subsequently at the Naval College, Greenwich, when the school was transferred to that place. In 1883 he left the Admiralty at the request of Lord Armstrong to organise the warship works at Elswick, but two and a half years later, on the retirement of Sir Nathaniel Barnaby, returned to the Admiralty as chief of the constructive staff, which position he held until ill-health compelled him to retire in 1902.

The introduction of the Naval Defence Act by Lord George Hamilton during White's régime, gave him a free hand in the question of battle-ship design, and he initiated a type from which those to-day have been steadily evolved. The turret with its low freeboard was replaced with a central armour belt and central fire batteries composed of twin barbettes, and there is still an influential section of naval opinion who consider this a better fighting type than the "Dreadnought," for which his successor, Sir Philip Watts, is responsible, and which is the latest official word on the question. Sir William White's design is the only modern one which has been put to the ordeal of combat, for Admiral Togo's victorious vessels were all built on his principles.

Although Sir William ceased to be Director of Naval Construction some ten years ago, he maintained an active interest in marine work, and served as adviser to many important companies, including the builders of the "Maure-

tania," The Parsons Turbine Company, The Grand Trunk Railway, and others. In 1885 he was made a K.C.B., and in 1902 his distinguished services were recognised by a vote of Parliament, while nearly every leading engineering society or institution has at one time or another honoured him with its presidency.

METHOD OF SECURING VANES AND BLADES IN STEAM TURBINES.

CONSIDERABLE ingenuity has been expended by turbine builders on the methods of securing the vanes and blades in the rotors and stators of this type of prime mover, and numerous patents have been granted at various times until now nearly all makers have their own special construction. Another method has just been patented by Messrs. Belliss and Morcom, Ltd., Ledsam Street Works, Birmingham, and is shown in the accompanying illustrations.

Referring to Fig. 1, A is a groove formed in the rotor or stator and having longitudinal lateral ridges D. B is the vane or blade which, by punching, is formed with a forwardly projecting tongue R. C is a distance-piece which by milling, is formed with a recess S in its back, the upper surface of which

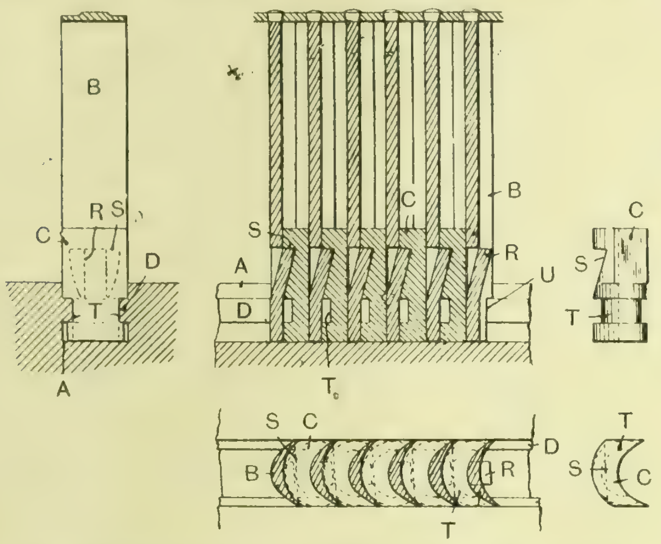
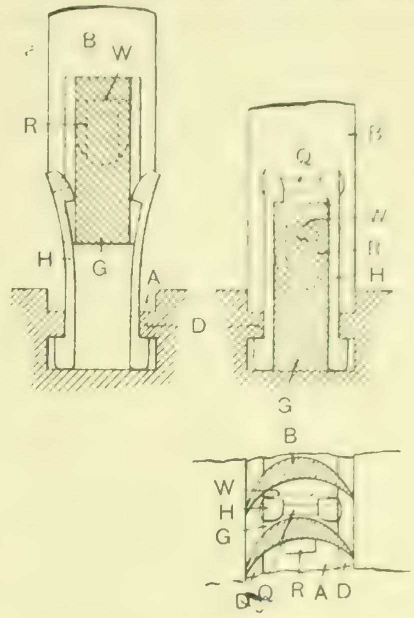


FIG. 1. METHOD OF SECURING VANES AND BLADES IN STEAM TURBINES.

recess engages over the tongue and thereby holds the vane or blade. The distance-piece C is of such width as to extend across the full width of the groove both above and beneath the ridges D, and is formed with a reduced portion or waist T to fit between the ridges D. The vane or blade is first placed in position in the groove, it being reduced in width at U to fit between the ridges D. The distance-piece C is then inserted in the groove with its width in the longitudinal direction of the groove, in which position the lower portion of the distance-piece can pass between the ridges D. The distance-piece is thereupon turned so that its width extends across the groove, in which position its base portion engages beneath the ridges D. If not tight back against the vane or blade, the distance-piece is then displaced longitudinally into close contact with the vane or blade, which latter is securely held by the engagement of its tongue R with the recess S in the back of the distance-piece.

For fixing the final vane or blade of a set, a bifurcated distance-piece E may be employed, as shown in Fig. 2, from which it will be seen that on crushing the distance-piece E into the groove, the fangs thereof become spread, by a short length of flat-sided rod F inserted in the groove, and engage beneath bevelled portions of the ridges D. The bifurcated distance-piece E has a recess V to engage the tongue R of the vane or blade. Another method of securing the final blade or vane, which does not involve destruction of the distance piece for its removal, is shown in Fig. 3. The distance piece G has a recess W for engagement with the tongue R of a vane or blade B, and is of a total width to fit between the ridges D of the groove A. On each of its two sides the distance-piece G is grooved to receive what may be called a pot-hook H. The outwardly directed hook at the lower end of each pot hook engages beneath the respective ridge D, whilst the inwardly directed hook at the upper end of each pot hook engages over the top of the distance piece G, where the two pot hooks may be tied together by a rivet Q. The shanks of the pot hooks



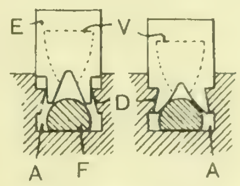


FIG. 2 FIG. 3

METHOD OF SECURING VANES AND BLADES IN STEAM TURBINES.

are sufficiently springy to permit the hooks at their upper ends to be forced apart when the distance-piece G is forced down into the groove.

Another method of locking the distance-pieces in the groove which does not require the distance-pieces to be turned, and which dispenses with a special final distance-piece, is illustrated in Fig. 4. In this construction instead of ridges there is a notch J formed in one side of the groove. A lateral notch K corresponding thereto is provided in the distance-piece C, and a segmental key-piece M is inserted in both notches by longitudinal displacement and locks the distance-piece in the groove. These key-pieces M are of a length to extend approximately twice the pitch of the vanes or blades B, so that each key-piece secures two distance-pieces. The vanes or blades situated midway of the length of each distance-piece are cut away, as shown at N, the alternate vanes or blades at the ends of the key-pieces being of the full width

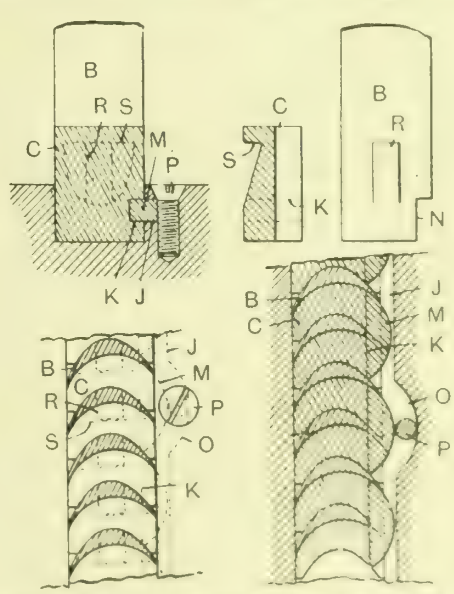


FIG. 4. METHOD OF SECURING VANES AND BLADES IN STEAM TURBINES.

of the groove. To enable the final pair of vanes or blades and distance-pieces to be secured, a recess O is provided in the notch J, whereby the last key piece M can be pushed into position laterally, where it is retained by a screw P. Obviously both sides of the groove and distance-pieces may be notched, and a set of key-pieces employed on both sides.

LIQUID FUEL FOR SHIP PROPULSION.*

BY C. ZULVER.

So much has of late been said and written on the use of liquid fuel as a source of power and of its advantages over coal that it appears to be difficult to express any original view on the subject. The ground has been already well traversed, but daily the importance of liquid fuel grows, both for shipowners and for the users of power on shore who are on the qui-vive for improved and more economical methods. Hence the justification for the contents of this paper. It may be explained beforehand that the writer does not propose to put forward any views of a speculative nature, and that on this occasion he wishes only to deal with facts gathered from actual experience. Thus, it is hoped, they will be of practical value to enterprising shipowners and other users of power meditating the adoption of oil fuel for either steam raising purposes or direct power production on pistons of internal combustion engines of Diesel or other type.

The writer proposes to deal in rotation with the following subjects bearing on actual results obtained from the use of oil fuel on board ship: (1) Comparison of fuel consumption in oil and coal on steamers, and the bearing on cargo-carrying capacity; (2) the institution of a very similar comparison between steamers and vessels fitted with Diesel engines; (3) risk of burning and carrying oil fuel as compared with coal; (4) reliability in actual service of coal and oil-fired ships and speed results obtained; (5) various systems for burning liquid fuel.

In comparing the fuel consumption of oil and coal-fired boilers and all steam engine plants on board ship, the consumption is, in most cases, given in indicated horse-power per hour, and the following figures have appeared in certain publications for natural or forced-draught fired boilers and ordinary triple-expansion engines: Consumption of oil per hour per indicated horse-power, 1·02lbs., 0·95lbs., &c. These figures are to be considered very economical if compared with the usual consumption of coal, being from 1·5lbs. to 1·6lbs. per indicated horse-power per hour; but, in the writer's opinion, they do not quite give a true idea of actual results obtained, *i.e.*, fuel consumption in relation to work done.

Fuel consumption per indicated horse-power per hour being a recognised standard for comparison and exclusively adopted, some explanatory observation in support of this view may not be out of place. The writer has found that the indicated horse-power as calculated from the cards may vary greatly for the same revolutions, in consequence of internal losses in the engine itself as influenced by different settings of slide valves, various arrangements of driving auxiliaries, &c., and it would therefore appear that with these varying conditions on board steamers, indicated horse-power per hour cannot quite be accepted as a true basis for comparison. It may also be observed that it is largely a theoretical basis, as the working out of a small indicator card easily allows of mistakes being made on either side. And a slight mistake either in taking a card with gear which is not of modern design—in very few ships it is—or in the subsequent calculations from the card, easily makes it possible to arrive at varying results. It has, for instance, been found that where in the one case the fuel consumption per indicated horse-power amounted to 1·25lbs., the actual result in speed and fuel consumption per day for the same displacement was considerably better than when the consumption worked out at 1lb. per indicated horse-power per hour, and that the indicated horse-power on paper—*i.e.*, on the cards—is by no means to be looked upon as giving a fair idea of the true power transmitted to the propeller.

The average shipowner does not care very much for theoretical figures; naturally, he is, as a rule, more interested to know the consumption of coal or oil fuel per diem in connection with deadweight and speed maintained. These figures define the fuel bill, which he is anxious to keep as low as possible, so that his ship may make a favourable showing in comparison with competitors. These few remarks will be sufficient excuse for deviating in the following pages from the general rule of giving fuel consumption in indicated horse-power per hour.

From a number of voyages of the same ship with the boilers burning either coal or oil, and the engines kept running as nearly as possible in the same condition as regards vacuum, revolutions, &c., it has been found that in a ship with deadweight carrying capacity of 7,700 tons, the consumption of oil works out over a series of years at about 22½ tons a day, against 32-33 tons of Welsh coal, or a mean saving, by weight, in fuel consumption of 33 per cent. As a direct consequence of this it was found that the ship carried about 150-200 tons more cargo when burning oil. The actual results obtained in the steamer "Conch" under these conditions, as copied from the vessel's log, are given in Table I.:—

TABLE I.—*Extract from Log of S.S. "Conch."*

Liquid Fuel.

Day.		Voyage.	Hours Steaming.	Miles.	Revs. per Min.	I.H.P.	Speed	Cons.
1910.		Feb. 10th to Mar. 19th.						
Feb.	12	Samboe to Rotterdam.	24·18	275	63·0	1561	11·3	22·5
..	13	Draught, fore, 25ft.;	24·19	284	63·0		11·7	22·5
..	14	aft, 26ft. 3in.	24·17	252	63·0		10·4	22·5
..	15	Cargo, 6,833 tons ben.	24·17	252	63·0		10·4	22·5
..	16	Deadweight, 7,902 tons	24·16	242	63·0		10·0	22·5
..	17		24·15	241	63·0		9·9	22·5
Mar.	16		23·48	238	65·3	1763	10·0	22·5
,,	17		23·46	225	63·0		9·5	22·5
,,	18		23·27	240	63·3		10·2	22·5

Coal.—Welsh and North Country.

Day.		Voyage.	Hours Steaming.	Miles.	Revs. per Min.	I.H.P.	Speed	Cons.
1910.		New York to B. India.						
Mar.	27	Draught, fore, 23ft. 7in.;	23·45	230	63·7	1670	9·7	33
..	28	aft, 27ft. 5in.	23·45	233	63·2		9·8	32
..	29	Cargo, 6,827 tons ker.	23·45	226	63·4		9·5	32
..	30	Deadweight, 7,761 tons.	25·45	235	63·5		9·9	32
..	31		23·47	217	62·9		9·1	32
Apr.	8		23·50	237	63·2		10·0	31
..	9		23·50	230	63·5		9·7	31
..	10		23·51	222	63·0		9·3	31
..	11		23·50	243	63·1		10·2	31

With regard to the speed attained by a ship consuming liquid fuel in comparison with a coal-burning boat, it has been found that an appreciably better speed is maintained by the oil-fired steamer. This is mainly attributable to the cleaning of fires being dispensed with and also to the fact that in the tropics, and when coming through the Red Sea, the full steam pressure is constantly maintained with the oil fuel, the boilers being fired mechanically, while in coal-fired ships considerable difficulty is often experienced in keeping up steam with a temperature in the stokehold of from 115° to 125° Fah. In summer in the Red Sea an even higher temperature is quite common. These conditions, coupled with the fact that in some ships an inferior quality of Indian or other description of coal is carried, make it clear that the advantages of liquid fuel are considerable and usually underestimated by those without actual experience of its use. Even in temperate climes, it has been found that the ships burning liquid fuel show much better results as regards speed in relation to consumption and upkeep of boilers, stokehold and bunkers. A further important factor is that no skilled firemen are required in ships burning liquid fuel. The installation, when placed in the engine-room, can be controlled by the engineer on watch, and requires no more attention than ordinary independent feed pumps, while one fireman can easily attend to 18 furnaces.

In comparing the enormous advantages derivable from oil fuel in conjunction with the Diesel ship with the use of coal in ordinary steamers, the following figures, obtained in actual working, the mean result of two years' running, may be found of interest. We propose to give a few comparative results obtained with the motor vessel "Vulcanus," which com-

* Paper read before the Institute of Marine Engineers.

menced service in February, 1911, and a steamer of slightly less carrying capacity, thus:

	"Vulcanus"	"Sabine Rickmers"
Length, B.P.	196ft. 0in. ...	200ft. 0in.
Breadth	37ft. 9in. ...	30ft. 6in.
M.D.	13ft. 2in. ...	18ft. 9in.
Draught, S.M.	12ft. 4½in. ...	16ft. 9in.
Block coefficient	·78 ...	—
Deadweight carrying capacity... ...	1,235 tons ...	1,269 tons
Displacement	2,080 tons ...	2,290 tons
Mean speed	8 knots ...	8 knots
Engines (6-cyl. 4-cycle, reversible Werkspoor Diesel, dia. 15¾in. × 23⅝in. stroke)		Dias. 17⅛in. × 28in. × 44½in., 27⅛in. stroke
Revs. of engines	160 per min...	80 per min.
Consumption per diem.	2 tons of oil...	11 tons of coal
Total number of staff and crew ...	16 ...	30
"Vulcanus" has European crew, cost per day	£6 6 5	
"Sabine Rickmers" has Chinese crew, cost per day ...	£9 0 7	

Extracts from the logs of both vessels are given in Tables II. and III., showing how fully have been realised the claims made for Diesel engines as regards economy in fuel consumption, &c.:—

TABLE II.—*Extract from Log of M.V. "Vulcanus."*

Day.	Voyage.	Hours Steaming.	Miles.	Revs. per Min.	I.H.P.	Speed.	Cons.
1911.	August 3rd to 26th.						
Aug. 5	Kustendje to Hamburg	22·34	177	172		8·0	1·95
" 6	Draught, fore, 11ft. 2in.;	21·2	165	172		8·0	1·87
" 7	aft, 12ft. 8in.	21·33	174	172		8·1	1·82
" 8	Cargo, 976 tons	23·45	189	172		8·0	1·98
" 9	Deadweight, 1,112 tons	24·15	183	172		7·5	2·02
" 10		24·15	184	162		7·6	2·02
" 11		24·14	174	162		7·2	2·02
" 24		23·46	188	170		7·9	1·98
" 25		12·5	96	170		8·0	1·00

TABLE III.—*Extract from Log of S.S. "Sabine Rickmers."*
Japan and P. Laut Coal.

Day.	Voyage.	Hours Steaming.	Miles.	Revs. per min.	I.H.P.	Speed.	Cons.
1912.	April 22nd to 30th.						
Apr. 22	Pladjoe to Saigon, via	8·40	86	85·5	520	10·0	5·0
" 23	Singapore.	19·59	174	85		9·1	11·0
" 27	Draught, fore, 15ft.	23·55	208	86·1		8·7	13·5
" 28	7in.; aft, 16ft. 5in. Cargo, 1,033 tons. Deadweight, 1,290 tons.	23·58	212	86		8·8	13·5
	June 20th to 27th.						
June 22	B. Papan to Bukum,	19·50	161	84·5		8·1	11·1
" 23	via P. Laut.	24·14	209	85·3		8·6	13·5
" 24	Draught, fore, 14ft.	24·10	201	83·5		8·3	13·5
" 25	3in.; aft, 16ft. 3in. Cargo, 1,013 tons. Deadweight, 1,225 tons.	24·12	222	84·1		9·2	13·5

With regard to the fuel consumption of the "Vulcanus," this, as will be seen above, has not been found to exceed two tons of solar oil per diem, or about one-fifth of the coal consumption of a steamer of like capacity. A striking example of the advantages associated with low fuel consumption is to be found in the fact that the vessel recently completed a voyage of 88 days without bunkering at any intermediate port. On this particular run she left Amsterdam on August 30th with 140 tons of fuel oil bunkers, loaded a cargo at Constanza, Black Sea, for Cette, proceeded thence to Batoum, and arrived back at Amsterdam on November 27th, a distance of some 10,750 miles. In the Bay of Biscay and North Sea, moreover, the "Vulcanus" was confronted by very bad weather. Nevertheless 6 tons of liquid fuel remained on board at Amsterdam after the voyage. Thus the total consumption was 134 tons in 65·7 steaming days, or 2·03 tons per diem. Having discharged cargo at Amsterdam the "Vulcanus" was dry-docked, and the engines opened up and cleaned. Beyond a few piston rings no renewals were found necessary, and after cleaning up the vessel left Amsterdam on December 19th on a similar voyage.

It is particularly satisfactory to be able to record that so far there has been no appreciable wear and tear of the engines, a fact doubtless attributable to the excellent material the engine builders put into the construction of the machinery. The wear and tear of cylinder liners, as ascertained on the last occasion, is shown by the figures in Table IV.:—

TABLE IV.—*Gauging of Main Motor Cylinders, December, 1912.*

	Top mm	Middle mm	[illegible]
Original size ...	400 ...		
No. 1	400·5	400·4	400·1
No. 2	400·6	400·4	400·1
No. 3	400·8	400·6	400·6
No. 4	400·7	400·4	400·0
No. 5	400·6	400·4	400·2
No. 6	400·4	400·3	400·1

These results are considered extremely good, and there is every reason to conclude that the cost of upkeep of a Diesel engine will be less than that of a steam engine and boiler plant, expense of maintenance of boilers particularly increasing as age advances.

The "Vulcanus" has now covered 45,600 miles, more or less, and her engines are estimated to have made over 12 millions of revolutions. Her cargo-carrying capacity actually shows itself to be some 12-15 per cent. more than on a steamer of equal dimensions, which circumstance is due to the greatly reduced weight of the bunkers carried and the lower weight of the machinery, so that, with the high freights now ruling, the earning capacity of the vessel is much in excess of a steamer of like size. As a matter of fact, reckoning on present advanced rates of freight, this advantage has been found to represent about £2,500 a year, which in a ship of these dimensions is a considerable sum, and it must be borne in mind that these statements are in no way hypothetical, but rest on a prolonged and even exhaustive experience. Nor have we touched upon the whole of the important advantages which the Diesel ship enjoys over the steamer.

TABLE V.—*Extract from Log of "M.V. Juno."*

Date.	Voyage.	Hours.	Miles.	Revs.	I.H.P.	Speed.	Cons. Including [illegible]	[illegible]
1912	Brazil to Hamburg.							
Dec. 23		1·0	8	112·0		8·0	0·72	0·17
" 24	Draught, 17ft. 5in.	24·2	199	108·0		8·27	4·85	4·10
" 25	fore; 19ft. aft.	23·52	204	108·0		8·54	4·85	4·10
" 26	Cargo, 2248·66.	23·51	229	115·5		9·64	4·90	4·15
" 27	Deadweight, 2,513	23·37	208	114·3		8·81	4·85	4·10
" 28	tons.	24·16	195	113·9		8·03	4·90	4·15
" 29		23·16	213	120·0		9·15	4·90	4·15
" 30		21·46	206	119·5		9·47	4·55	3·80
" 31		24·19	228	118·0	1323	9·38	4·95	4·20
1913								
Jan. 1		24·19	322	117·7		9·43	4·95	4·20
" 2		24·18	222	119·6		9·13	4·95	4·20
" 3		23·51	216	116·7		9·05	4·85	4·10
" 4		23·21	197	113·6		8·43	4·75	4·00
" 5		23·54	197	111·7		8·24	4·75	4·00
" 6		22·55	205	114·3		8·94	4·69	3·90
" 7		23·44	222	116·8		9·35	4·85	4·10
" 8		23·41	212	115·4		8·94	4·85	4·10
" 9		22·49	204	115·3		8·94	4·65	3·90
" 10		8·30	51	112·1		6·00	4·25	1·45

To set down those not easily reducible to figures, it may be stated that with the Diesel ship stand-by losses in port show at a minimum, while with the coal-burning steamer the amount of fuel consumed lying with the banked fires is considerable. The maintenance of boilers, again, as all engineers know, is a costly matter. The expense, too, has a tendency to grow with their age. In the not infrequent necessity of repairing boilers during a voyage much time is lost in waiting until the boilers have cooled down sufficiently for work to be started and again lost in getting up steam. The greatest advantage of the Diesel vessel, next to a very low fuel consumption, is perhaps the absence of boilers with its corollary of saving in weight and space, and, as already mentioned, greater cargo-carrying capacity and fewer firemen. Briefly, to recapitulate the position: (1) The deadweight carrying

capacity is from 12 to 17 per cent. more; (2) smaller size of ship for a particular deadweight, hence lighter expense; (3) size for size the liquid fuel bunker will take the vessel five times as far as the coal bunker—a great desideratum in both the man-of-war and the merchant ship—and otherwise useless spaces, such as fore-peak double bottom, &c., can be used for its storage.

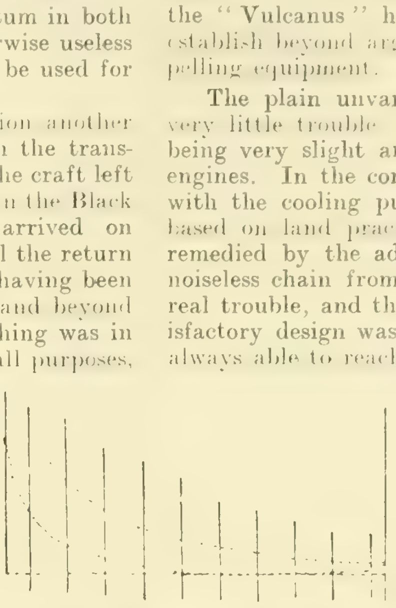
While this article was in course of preparation another motor vessel—the "Juno"—started her career in the transport of petroleum. After satisfactory trial runs the craft left Rotterdam on November 22nd, bound for Braila, in the Black Sea, where, after a prosperous passage, she arrived on December 15th. Having loaded a full cargo of oil the return voyage was commenced on December 22nd, after having been seven days in port to examine piston rings, &c., and beyond a few piston rings being found stuck fast everything was in good condition. The total fuel consumption for all purposes, excluding port use, worked out at 86·21 tons, or 4·75 tons per diem, which, for a displacement of 4,200 tons and mean speed of 9 knots, may be considered eminently satisfactory. An extract from the log of the m.v. "Juno" is given in Table V.

The "Juno" left Rotterdam for Braila on November 22nd, 1912, with 217·66 tons bunkers. She took 26·56 tons bunkers in Braila and arrived back in Amsterdam on January 13th, 1913, with 48·85 tons oil remaining. The consumption for all purposes amounted to 195·37 tons; deduct from this port and Danube River consumption, amounting to 19·37 tons, we find that she consumed 176 tons in full sea, including all auxiliaries, or 4·92 tons per day of 24 hours. Her main motor alone consumed 148 tons or 4·14 tons per day of 24 hours. It may be mentioned that the auxiliaries in the "Juno" are driven by steam. The donkey boiler is fired partly by the exhaust gases of the main motor and partly by liquid fuel directly injected into the furnaces. It was found that the heat contained in the exhaust gases was not quite enough to keep up full steam at sea, and occasionally the burners had to be used.

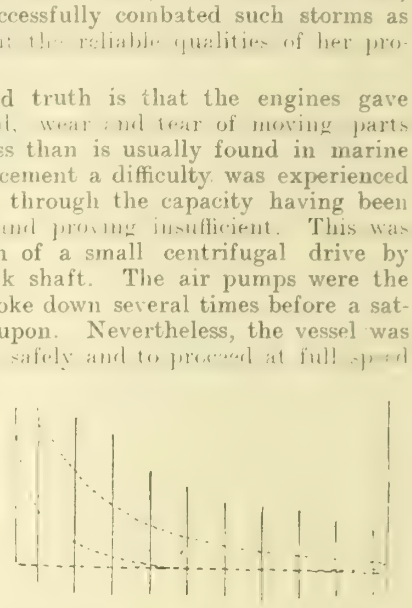
The fuel consumption of main engines worked out at 0·31lb. per indicated horse-power per hour. This figure is exceptionally low, but the author believes that it would hardly be fair to the steam engine to use it for the purpose of comparison; for, particularly in the case of the Diesel engine, a good portion of the horse-power is lost in the engine itself through the driving of air compressors, &c. The author's experience and investigation show that at least 30 per cent. should be deducted, and in small engines up to 35 per cent., to arrive at the brake horse-power. Allowing for a difference of 30 per cent., the consumption for the main engines of the "Juno" works out at 0·43lb. per brake horse-power per hour, and the total consumption, including all auxiliaries, at 0·40lb., which is about 17 per cent. less than for the 2-cycle engine. It is now desired to place before you a set of cards taken by the chief engineer on the run from the Black Sea to Hamburg—see Fig. 1.

Before turning to the subject of the use of liquid fuel under steam boilers, where in existing and projected tonnage it has also a promise of ever-extending adoption, something should be said concerning the mechanical difficulties experienced in running Diesel engines at sea. From over two years' practical association with the subject, the writer is of opinion that, as regards the 4-cycle Diesel engine, no deviation from satisfactory and continuous running need be apprehended in the different phases of the weather. The 4-cycle Diesel engine has functioned admirably in long non-stop runs, and a small Diesel ship, the "Sembilan," performed a non-stop voyage from Aden to Sabang—some 3,600 miles—in the beginning of 1911. The "Vulcanus" has made lengthy continuous trips under severe meteorological conditions, and it may be recalled that she was in the Bay of Biscay during the destructive gales that were a feature of the Christmas season. In both this and last winter, as a matter of fact, the "Vulcanus" has successfully combated such storms as establish beyond argument the reliable qualities of her propelling equipment.

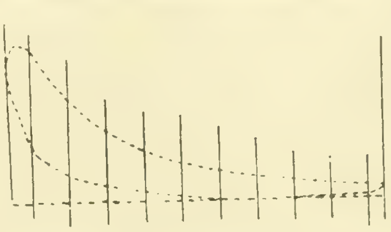
The plain unvarnished truth is that the engines gave very little trouble indeed, wear and tear of moving parts being very slight and less than is usually found in marine engines. In the commencement a difficulty was experienced with the cooling pumps, through the capacity having been based on land practice, and proving insufficient. This was remedied by the addition of a small centrifugal drive by noiseless chain from crank shaft. The air pumps were the real trouble, and they broke down several times before a satisfactory design was hit upon. Nevertheless, the vessel was always able to reach port safely and to proceed at full speed by means of the auxiliary Diesel engine driving the air compressor. It may here be stated that the "Vulcanus" has no donkey boilers and is entirely dependent on motor power.



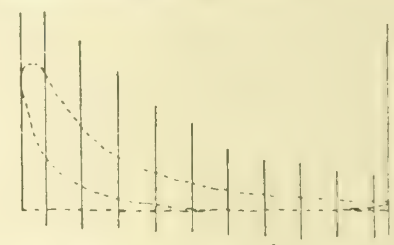
Cylinder No. 1. R.P.M., 120. I.H.P., 203·5.
Mean Pressure, 91·14lbs. per square inch.



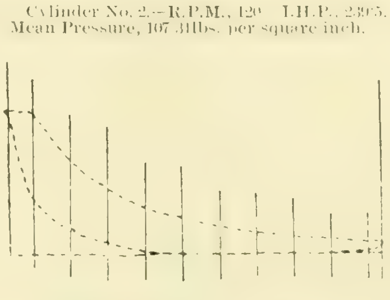
Cylinder No. 4. R.P.M., 120. I.H.P., 218·5.
Mean Pressure, 97·75lbs. per square inch.



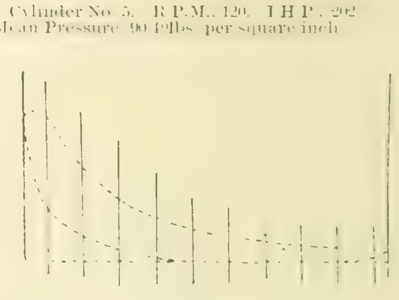
Cylinder No. 2.—R.P.M., 120. I.H.P., 239·5.
Mean Pressure, 107·31lbs. per square inch.



Cylinder No. 5. R.P.M., 120. I.H.P., 202.
Mean Pressure, 90·49lbs. per square inch.



Cylinder No. 3. R.P.M., 120. I.H.P., 233.
Mean Pressure, 104·37lbs. per square inch.



Cylinder No. 6. R.P.M., 120. I.H.P., 226·5.
Mean Pressure, 101·43lbs. per square inch.

Revs. per min.: 120 Diam. of cylinders, 560 m m
Stroke: 1000 m m.

I.H.P. Cyl. No. 1, 203·5. Cyl. No. 2, 239·5.
Cyl. No. 3, 233. Cyl. No. 4, 218·5.
Cyl. No. 5, 202. Cyl. No. 6, 226·5.
Total I.H.P. 1323.

Injection Air: 852·6lbs. per square inch.
Cooling Water Temp.: 110° Fah.
Temp. of Exhaust Gases: 695 Fah. or 370 C.
Fuel used per I.H.P. per hour: 0·1327 kg. or ·29lbs.
Fuel consumption per B.H.P. per hour (B.H.P. = 70 per cent. of I.H.P.): ·38lbs.
Overall consumption, including auxiliaries: ·41 lbs.

FIG. 1.—INDICATOR CARDS FROM THE MOTOR SHIP "JUNO."

The exhaust valves, which are usually looked upon as a weak point in the 4-cycle Diesel engines, have given no trouble on the "Vulcanus," although the precaution was taken to grind them in, or put the spare valves in after about a fortnight's or three weeks' running, the old valves with their seats then being ground in again at sea. No inconvenience or delay has ever been caused in this respect, it being quite an easy matter to fit a set of spare valves and seats.

To record the further mishaps that have befallen the "Vulcanus," it should be stated that on her third voyage to Hamburg the brick lining of the exhaust pipe collapsed, thus partially choking the exhaust passage. This reduced the revolutions of the engines, and the engineer, not knowing the cause, and being too much under the influence of his training in steam, further opened the throttle, thereby considerably overloading and choking the motor, which resulted

in the gases escaping into the engine room, and the exhaust pipe becoming red hot, and soft. This was the only occasion on which the "Vulcanus" had to be assisted. She was towed from the Elbe Lightship to Hamburg, but returned under her own power after four days' delay at Hamburg. Secondly, there was a bending of the crank shaft on a trip from Rotterdam to Barrow, due to one of the bottom end bolts breaking and fouling the crank, so bringing the engine to a sudden stop. Still, this bent crank shaft, and consequently disturbed timing of the "Vulcanus," did not prevent the boat from running another three months, when a new shaft was put in. A third incident was the exploding of an inblast air vessel, which cost the second engineer his left arm. This was a most distressing and unfortunate accident, and happened while the engines were being tried after overhauling in the yard of the builders. Bad welding had left a fracture, and the top part of the air vessel blew right off; but the indirect cause of the accident was probably the accumulation of water in the air vessel which had not drained because of an internal pipe being cracked. This mishap taught us not to use any more welded air vessels, and to suspend the vessel with cover and valves downward, which effectually prevented any unknown accumulation of water.

(*To be continued.*)

BLOWHOLES IN VALVE CASTINGS.

In a recent issue of "The Brass World" attention is directed to the difficulty experienced by a valve manufacturer in making sound valve castings. The difficulty was caused by the presence of blowholes. The existence of blowholes in valve or other castings is a very common occurrence, but this manufacturer believed that they were caused by a certain ingot metal he had been using Troubled by the blowholes, the ingot from which the castings were made was considered as the cause of the trouble and one of them cut in half, with the result that a blowhole was discovered. This blowhole was probably caused by air. When the metal was poured into the ingot mould, the air became entangled and remained there. This blowhole was large and of a kind often found when an ingot has been poured at a rather low heat. Even though it might have been gas of a different nature from air, it would have no bearing upon the blowholes in the casting for the reason that it would escape when the ingot metal was melted. Blowholes in sand castings almost entirely come from the gases generated by the combustion of the fuel during the melting and become absorbed during the melting. As the metal cools in the mould, these gases are expelled forming blowholes. Blowholes and pinholes are the same and are produced by gas absorption. One is simply larger than the other.

The reason why, with the same manner of melting and the same metal, blowholes will be present in one casting and not in another is in the method of melting. All fuels used in the brass foundry at the present time contain sulphur and, of course, various gases such as carbon monoxide, hydrogen, carbon dioxide are generated by the combustion of the fuel. It is the sulphur that is a very common cause of the trouble, although the other gases play an important part. When the metal melts, it absorbs these gases and then, after it has been cast in the sand mould, they are expelled and blowholes form. In melting, therefore, the metal should be protected against these gases. A common and excellent method is to keep the surface of the metal covered with charcoal. Charcoal contains no sulphur at all and, for this reason, it introduces none into the metal. At the same time, it forms a covering which burns and has a reducing action and thus prevents the formation of oxide. It has been found that many cases in which foundrymen have had trouble with blowholes in their castings, have been caused by failure to use any charcoal at all for covering the metal during the melting. In the best regulated establishments and those which turn out the best metal, charcoal is extensively employed and is introduced into the crucible as soon as the metal melts. A better plan, and one carried out in many brass-casting plants, is to put some into the crucible when the metal is introduced. In this manner, the metal is protected as soon as it begins to melt. Coal or coke will not answer in place of the charcoal as they contain sulphur.

There is another feature in melting that causes blowholes in the metal and that is overheating. The hotter the metal the more readily will the gases be absorbed. It will not suffice to overheat the metal and then cool it down with scrap. The gases have been absorbed during the melting and are there to do the harm. The right procedure is to bring the metal up to the right melting point which is necessary for pouring the castings, but not allow it to go beyond it. In addition the feature of allowing the metal to "soak" in the fire is detrimental to it. It is a very common thing to have metal ready long before the mould is finished. Then, as it cannot be poured, the metal must remain in the fire until the mould is ready and it then has a longer opportunity to absorb sulphur and gases. Should the metal happen to become overheated during this "soaking," as it frequently does, then there is all the more chance for gas and sulphur absorption and the castings will contain more blowholes.

In melting the following rules should be strictly obeyed. It makes no difference whether the metal is yellow brass, composition, or steam metal, the procedure is the same as the same principle applies. (1) Add a little charcoal to the crucible before melting so that as soon as the metal begins to melt and run down to the bottom it will be protected by it. (2) As soon as the melting begins add a little more charcoal so that there is always a depth of half or three-quarters of an inch on the surface of the molten metal. (3) Never allow the charcoal to burn off from the top of the metal, but add more if required. (4) Do not overheat the metal beyond the actual pouring temperature. (5) Do not allow the metal to remain in the fire after it has melted, but have the moulds ready for pouring before it is melted. If these directions are followed, blowholes will not bother a brassfounder as he will then rarely have them.

BOOK REVIEWS.

Textbook of Applied Mechanics and Mechanical Engineering. By Andrew Jamieson, M.Inst.C.E., formerly Professor of Engineering in the Glasgow and West of Scotland Technical College. Vol. I.; Applied Mechanics; ninth edition; revised and enlarged. London: Chas. Griffin & Co.; 5½in. by 7¾in.; 412 pp.; price 6s.

This textbook has been so long before the engineering public, and its general merits are so well known that there is no call for special description of them, especially as the volume has been previously noticed in these columns. We note, however, that the present edition was revised by the author shortly before his decease, and some additions made to previously unanswered questions taken from the Board of Education, the City and Guilds, and the Civil Engineers' examination papers. Certain additions have also been made to the Appendix dealing with practical electrical units, to make it in keeping with symbols provisionally adopted by the International Electrotechnical Commission at Turin, in September, 1911.

* * *

Iron and Steel. An introductory textbook for engineers and metallurgists. By O. F. Hudson, M.Sc., with a sketch on corrosion by Guy D. Bengough, M.A., D.Sc. London: Constable & Co.; 9in. by 6in.; 173 pp.; price 6s. net.

The contents of this book are altogether too superficial and brief for the professed object of its authors, viz., to present the more important principles of the metallurgy of iron and steel, and few engineers or users of the multifarious varieties of these alloys will find it of much help in the kind of problems that arise in practice. If difficulties do present themselves an engineer is pretty certain to require more aid than is afforded by the cursory treatment here given.

BOOKS RECEIVED.

Elements of Hydraulics. A textbook for secondary technical schools. By Mansfield Merriman. New York: John Wiley and Sons. London: Chapman & Hall. Price 4s. 6d. net.

Bells, Indicators, and Telephones. By J. B. Redfern. J. Savin Electrical Installation Manuals. Constable & Co., London: price 1s. 6d. net.

Bulletin No. 29 of the Engineering Experiment Station of the Iowa State College of Agriculture on the costs of producing power in Iowa with Iowa Coals.

MESSRS. MATHER & PLATT'S PARK WORKS, MANCHESTER.

There are few engineering firms whose manufactures range over a wider field, and fewer still who have been more uniformly successful than that of Messrs. Mather & Platt, of Salford Ironworks, Manchester. This consummation has only been attained by the exercise of an alertness and a foresight that anticipated the lines of advance along which progress was being made. Lancashire has supplied as many illustrations of this business versatility, perhaps, as any other county, and though there have been some old establishments that have shown an inability to keep abreast with the rapid changes that have characterised engineering during the last half century, this firm have in many ways demonstrated that it has been possible not only to do so, but to thrive upon it.

Established early in the last century, the firm was at first chiefly concerned with the manufacture of textile machinery for bleaching, dyeing, printing, and finishing cotton goods, and it was not until many years afterwards that electrical engineering, in which they may be said to have been pioneers, was taken up and subsequently developed into a very important branch. They also specialised in hydraulic plant, water filtration, sewage purification, well boring, and pumping installations, and were the original makers of the turbine pump. Some 30 years ago the question of how to provide more efficient means of protection against fire began to loom large in this country, as it had previously in the States, and led to a demand for improvement in fire extinguishing apparatus. Messrs. Mather & Platt were the first in the field with the Grinnell automatic sprinkler, which has since won for itself so world-wide a reputation. With such a widespread variety of manufactures many firms would have been inclined to "mark time." This, however, has never been their motto. The steam turbine and the large gas engine both held out promises of great things, and their manufacture was forthwith taken up.

Fig. 1.—View of Park Works of Messrs. Mather & Platt, Ltd.

In the meantime space on the old site in Salford was becoming quite exhausted, and as there was no room for extension, except in an upward direction, it was decided to secure a site on which to build new and more suitable works. A very suitable plot of 50 acres was secured at Newton Heath, adjoining the Lancashire and Yorkshire, Midland, and North-western Railway systems, and in 1901 building operations were here commenced. The portion in the centre of the main block in the general view and plan, was erected in that year, and comprised an administrative building of two storeys and a machine shop, the latter being 376ft. long, with a width of 130ft. in four bays. It was built of iron and steel stanchions with T-iron stays and supports for the roof, and, in fact, was the original machinery hall of the Paris Exhibition of 1900. This building is used for the fire engineering section of the firm's business, and includes the manufacture of the Grinnell automatic sprinkler, cast-iron fittings, pumps, valves, tanks, and other fire appliances, whilst the pipe shop occupies two of the bays.

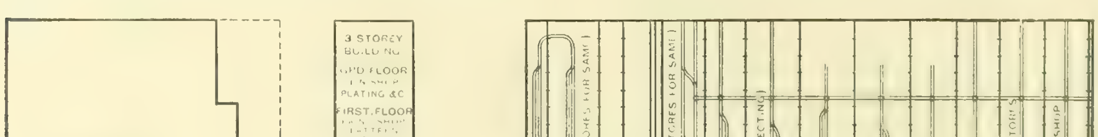


Fig. 2.—Plan of Park Works of Messrs. Mather & Platt, Ltd.

The administrative block is a building erected somewhat on American lines. The outer walls are of brickwork, and although non-fireproof, it is of slow-burning construction, with flooring consisting of wooden joists placed close together on edge, and with a covering of maple to give a smooth surface. The arrangement and equipment of the administrative departments have been designed with a view to systematic management and efficiency without unnecessary expenditure on ornate fittings. The main offices are open from end to end, and only the directors and managers are provided with separate rooms. A few years later the pressure on the electrical department at the old works at Salford made further extensions at the new site desirable, and for the accommodation of this section two more bays, each 376ft. long and 40ft. wide, were erected. Again in 1910 it was decided to make further extensions, and a commencement was made with a struc-

ture comprising seven bays of the same length as the last, but 52ft. 8in. and 42ft. 8in. wide. The construction of this building is generally similar to that erected in 1901. The floors are of concrete, prepared and covered with wooden blocks, and laid in with pitch.

In 1911 the building on the extreme left of the plan and general view was erected. It is a two-storey fireproof structure, 218ft. 6in. long by 48ft. 6in. wide. The upper floor is used for administrative purposes and the lower floor has been equipped as a dining-room and kitchen with accommodation for over 1,000 men. The dining-room is divided into compartments for the different grades of workpeople. A hot dinner is provided every day at a moderate price, and those men who bring their own food can have it warmed or obtain hot water without any charge. The offices above communicate with the older offices by means of a reinforced concrete bridge shown in the general view. Adjoining the ground floor of this building is the workmen's lavatory. This is fitted up with long cast-iron troughs which are filled with warm water at meal times and each man is provided with soap and towel. In this building lockers constructed of metal, and well ventilated, are provided so that each man has a place in which to hang his coat, it being forbidden to take these into the shops. Another new building is a three-storey structure at the rear of the power-house (see plan) of fireproof construction throughout with steel framework, with reinforced concrete floors and roof. In designing the building special attention was paid to the question of light, and the window areas are exceptionally large. It is occupied on the top floor as a pattern shop, the first floor as pattern stores and paint shop, and the ground floor as a tinsmith's shop and for cotton bowl making.

FIG. 3.—HEAVY MACHINE SHOP AT PARK WORKS OF MESSRS. MATHER & PLATT, LTD.

The latest addition to the establishment is a building with seven bays used as a brass and iron foundry and smithy. It measures 275ft. by 218ft. 6in., and is supplied with materials by a line of rails running from the firm's siding on the Lancashire and Yorkshire Railway, from which siding lines also run into bays in each department of the works, so that the raw material and finished products can be unloaded and loaded direct without unnecessary handling. In addition to these lines of standard gauge a complete system of narrow gauge tramway lines, 21½in. gauge, is laid in each bay, fitted with trucks capable of carrying two tons, for the purpose of rapidly conveying goods from one department to another.

The trucks run on roller bearings to reduce friction and can easily be pushed about the shops by one man.

All the bays of the main building are of the same length. The average height under the cranes is 24ft., and each shop is served by an overhead electric travelling crane running the whole length of the building. In addition, pneumatic hoists and jib cranes operated by hand are placed over the benches for handling small work. The shops are illuminated at night by means of metal filament lamps, each of 1,000 candle-power, distributed equidistantly from one another and so arranged to avoid the throwing of shadows. The ventilation and heating have also been well considered. The latter is effected by hot water at low pressure, each bay having its own battery of heating pipes running the full length. The water is heated in

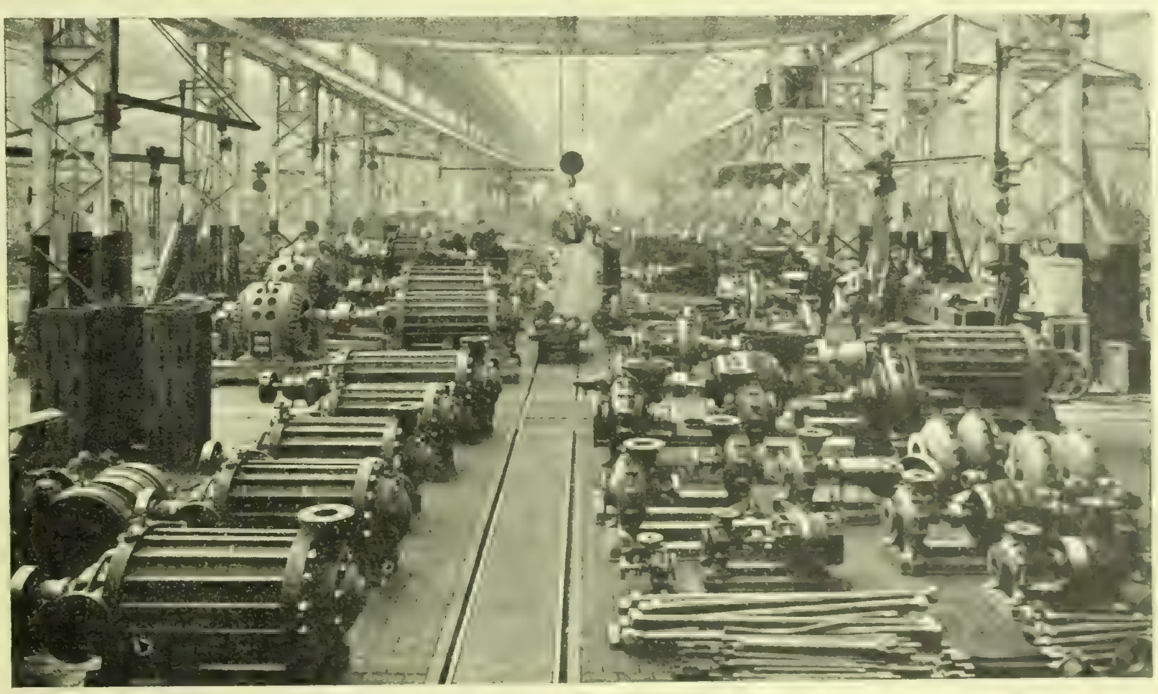


FIG. 4.—PUMP DEPARTMENT AT PARK WORKS OF MESSRS. MATHER & PLATT, LTD.

boilers and is caused to circulate throughout the whole installation by means of a centrifugal pump, which maintains an even flow of 5,000 galls. of water per hour.

The energy to drive the whole of the works is taken from the Manchester Corporation electric supply mains. Alternating current is brought into the works at a pressure of 6,500 volts and is transformed in the power house (see Fig. 8) down to direct current at 440 volts. It is distributed on the three wire system, so that two pressures are provided. The large machine tools are driven independently by their own electric motors and the lighter tools are operated from sections of overhead line shafting, each section being driven by its own motor. An underground brick culvert is laid from the power house right across all the bays to accommodate and afford easy access to the electric cables for power and lighting, as well as to the steam, gas, and pressure water pipes for testing purposes.

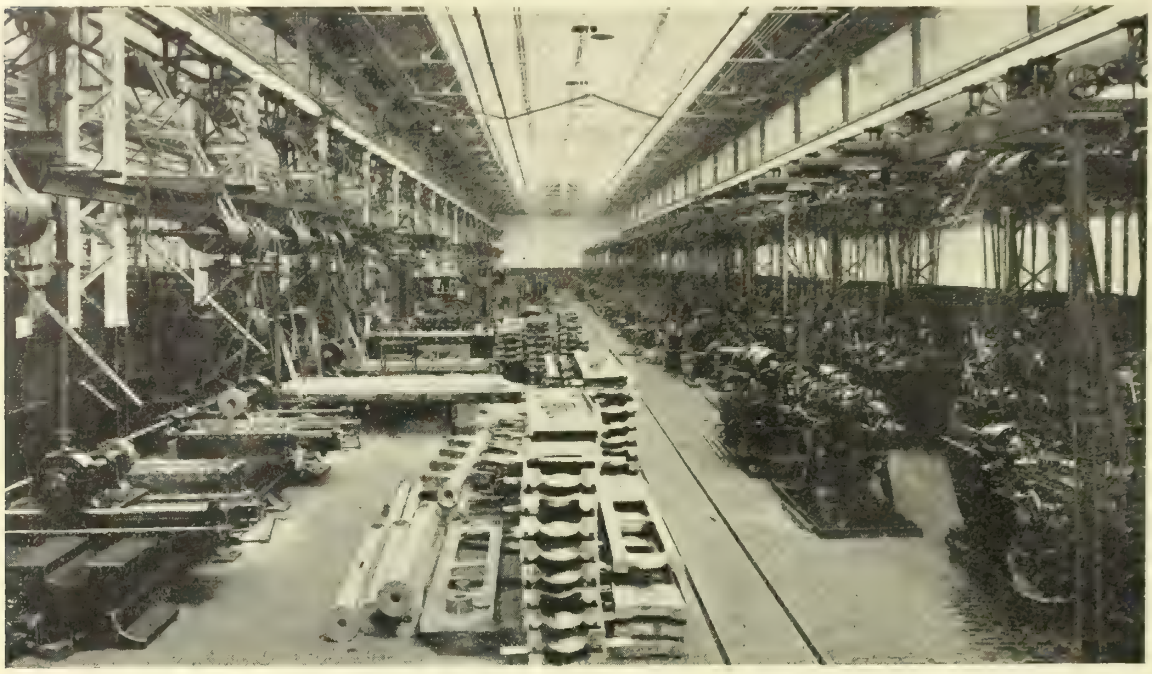


FIG. 5.—AUTOMATIC TOOLS AND TURRET LATHES AT PARK WORKS OF MESSRS. MATHER & PLATT, LTD.

Water for manufacturing, fire, and other purposes is obtained from a large reservoir into which all the rain water from the roofs, &c, is drained. From this reservoir the water is forced by means of a turbine pump through one of the firm's mechanical pressure filters, which has a capacity of 6,000 galls. per hour, and thence into an elevated tank placed in the tower shown in the general view, whence a constant pressure is maintained in the circulating mains. For drinking and other purposes the supply is taken from the Corporation mains.

The whole of the offices and shops are equipped with a model fire extinguishing plant. This includes some 4,000 Grinnell sprinklers divided into eight distinct installations, each controlled by a separate set of 6in. alternate wet and dry pipe valves. These eight installations are maintained under water pressure during the summer months, but to guard against the effects of frost in the winter the water is drained out of all the pipes above the main valves and air is pumped in under pressure. Water is supplied by an 8in. pipe from the Corporation main, augmented by a gravity tank of 10,000 galls. capacity and an electrically driven turbine pump capable of delivering 1,000 galls. per minute. In connection with this pump there is provided automatic starting gear. Briefly, this consists of a vertical hydraulic cylinder in which is a weighted ram; the latter is held in position at the top of the cylinder by means of a catch controlled by the pressure of water in the sprinkler installation. When this pressure is reduced to a predetermined extent by the opening of one or more sprinklers in case of fire, the catch releases the ram, which falls by gravity and starts the electrically driven turbine pump, which continues to work until stopped by hand. As soon as the pump has been started the ram is automatically raised again to its former position and is ready to start the pump afresh should occasion arise. From the above it will be gathered that the pump has not to be kept running continually, yet is always ready when required. In connection with the sprinkler installation is a simple and efficient fire alarm, which immediately gives warning in case of even a small escape of water inside the building, whether the escape be due to a leaky joint, a faulty pipe, or the operation of a sprinkler. The alarm, which is operated by a valve connected with a small water wheel having revolving hammers which beat against a gong, continues to sound as long as the escape takes place.

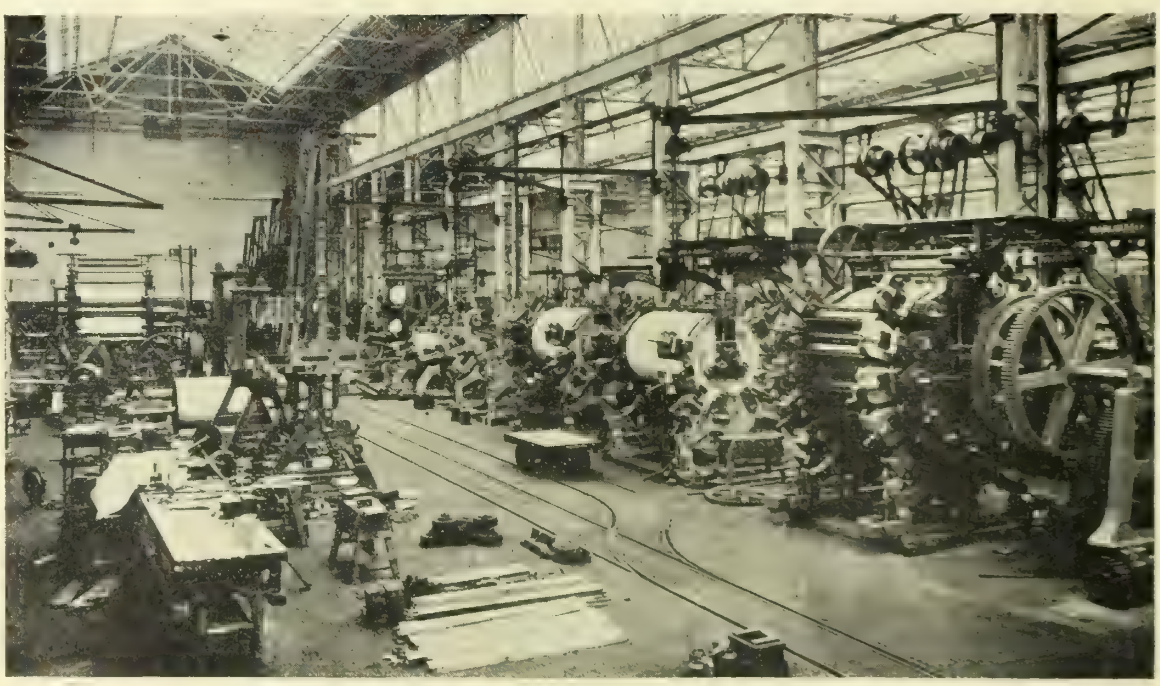


FIG. 6. TEXTILE DEPARTMENT AT PARK WORKS OF MESSRS. MATHER & PLATT, LTD.

BUILDINGS FOR ENGINEERING WORKS.

An interesting paper entitled "The Construction and Arrangement of Buildings for Engineering Works" was read by Mr. H. N. Allott, M.Inst.C.E., at a meeting of the Manchester Association of Engineers, held on Saturday last. The lay-out and dimensions of the shops must, he said, in all cases be determined by the purpose for which they were intended to be used, and also by the shape and levels of the site. This was especially the case in buildings to be erected in town neighbourhoods, more freedom being possible in country districts where land was more easily obtained. In all cases it was advisable to arrange works so that continuity might be obtained as far as possible. It was not possible to arrange in every case that the raw material should be put in at one end and the finished article turned out at the other, but it was always possible by a proper arrangement of shops to minimise the handling and the distance travelled by the work in its progress through the shops. Another point to be borne in mind was the possibility of extension, and it was in most cases feasible by a proper consideration of this point to minimise trouble and expense in carrying out future alterations to meet an expansion of business.

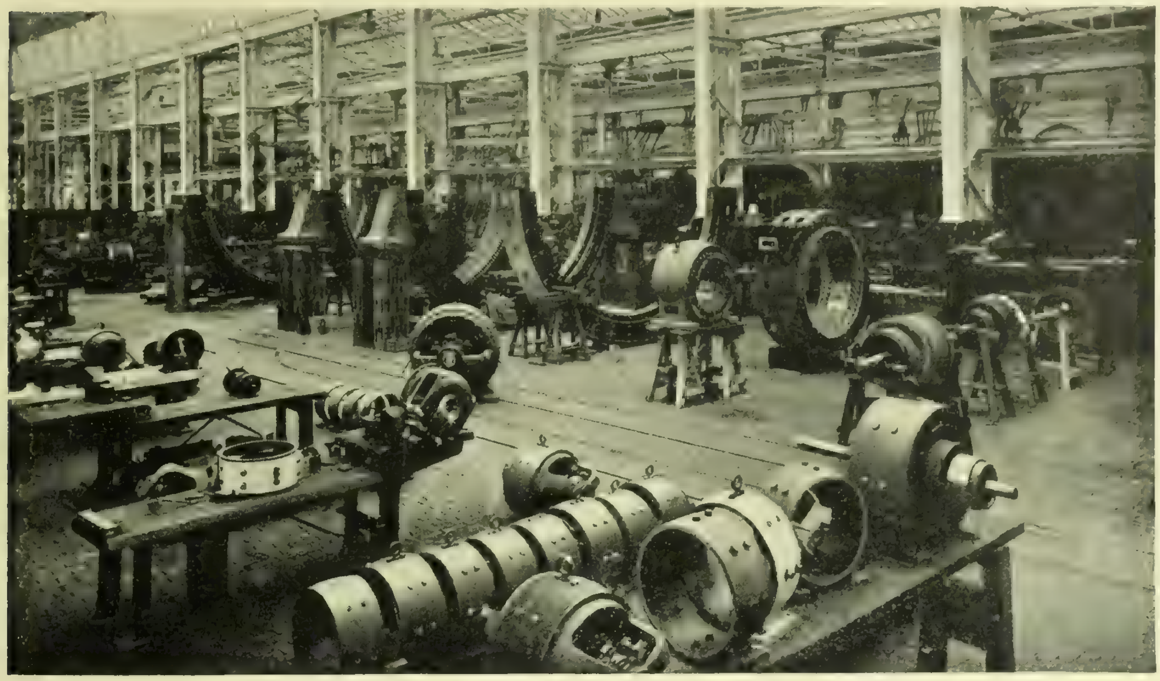


Fig. 7.—Electrical Department at Park Works of Messrs. Mather & Platt, Ltd.

The type of building to be adopted would be determined by the description of work to be carried out. Generally speaking, for small work where heavy cranes were not required, and where the type of machinery employed was small, the sawtooth type of roof would be found most convenient; whilst for shops where the machines and the work were of a heavier description, and the spans consequently greater, a ridge roof was the best arrangement. The author next described the lay-out of an ordinary engineering shop of moderate size, arranged all on one floor with small bays on one side for light tools and fitting, and wider and higher bays for heavier machine tools and erection purposes. There was, he observed, no doubt that for ordinary engineering purposes the arrangement of shops on one level was most convenient, as this allowed of better supervision, better access between the various shops, and better light than was possible where the works were arranged in buildings of more than one storey. Buildings of more than one storey were as a rule used only in cases where the work and the machinery used were of a light description. There did not seem to be anything to recommend the building of works of more than one storey than the question of the area covered, where economy of land was of more importance than the extra cost of building involved.

The first matter to be decided in designing the workshop buildings after laying down the plan was, he remarked, the height to the underside of the roof, which depended on the height of lift, and the head room required for the cranes, and where these were not necessary on the height required for driving the machines. In the example dealt with by the author, a height of 30ft. was allowed for the erecting and heavy machine shops, and 15ft. for the light machine and fitting shops. The roofs of all the bays were of the ridge type. The smaller bays of roofing were also of this description, since sawtooth roofing should not, generally speaking, be of a greater span than 25ft. The widths of bays depended on the machines employed and the character of the work to be carried out, and where these matters could be arranged to suit a bay of not more than 25ft. in width a roof of the sawtooth type was undoubtedly the

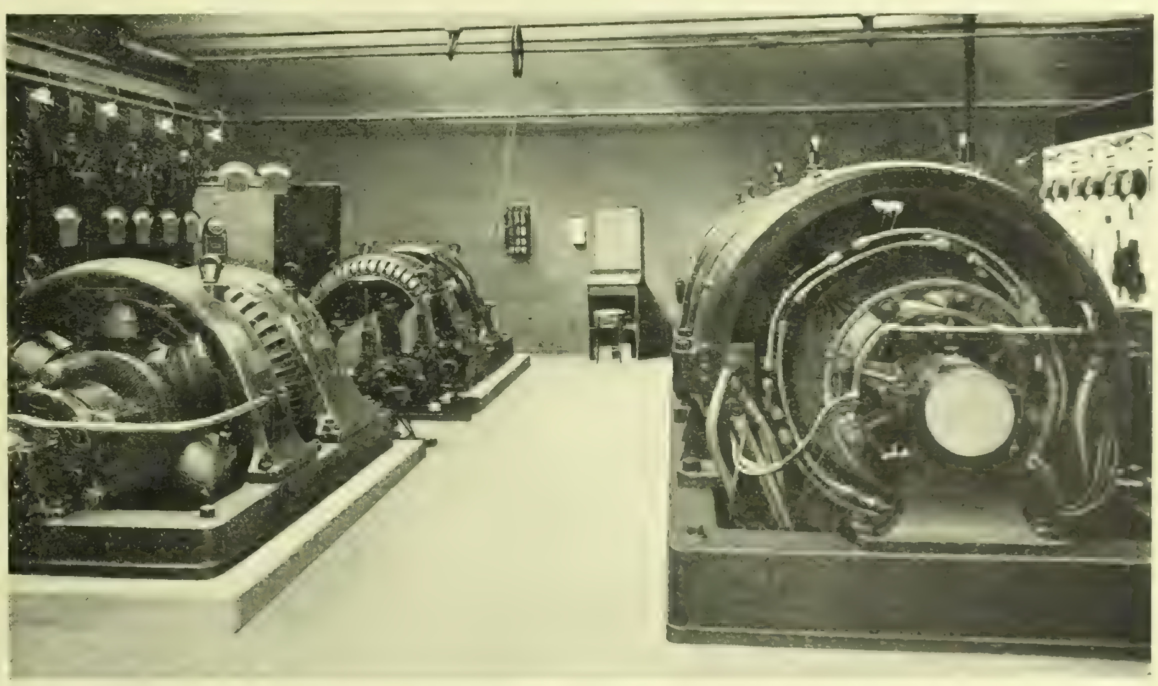


Fig. 8.—Power House at Park Works, Equipped by Messrs. Mather & Platt, Ltd.

best. Sawtooth roofing where possible was usually arranged with the glazing facing north so as to prevent the direct glare of the sun through the glass. The principal advantage of the sawtooth roof was that by its use a more evenly lighted and cooler shop was obtained.

The amount of glazing to be allowed for in a roof of the ridge type should not be less than about 50 per cent. of the area of covering, and in districts with an atmosphere like that of Manchester this might be increased with advantage to 60 per cent. or 70 per cent. The glass should be equally distributed on both sides of the roof, as by that means a more even illumination was obtained than when all the glass was placed on one side of the roof. Another advantage of distributing the glazing was that the direct glare of the sun and consequent heating of the shops in summer was minimised.

The roof covering in this country usually consisted either of slates, asphalte felt, or corrugated iron. For slates or corrugated iron the roof generally was given a rise of not less than quarter of the span, for if made of a flatter slope rain and snow were liable to blow in at the joints. For felted roofs the roof might be practically flat if the joints were properly made with mastic, and it was only necessary to give a fall of one or two inches to the foot to allow for drainage. Galvanised corrugated iron was usually only used in this country for buildings required for temporary purposes, and when used should be carefully painted before and after fixing, and afterwards properly maintained, as otherwise its life was only short. The roof glazing was best carried out with patent glazing, of which there were several satisfactory makes on the market, the alternatives to patent glazing being wood or tee steel glazing bars, the glass being puttied in. The patent glazing was preferable. The roof glazing was best carried out with wire wove glass.

In a machine shop the number of cubic feet of air space was generally sufficiently large, in comparison with the number of men employed, to render extensive roof ventilation unnecessary, and sufficient ventilation might be provided by opening sashes in the glazing to a sawtooth roof, or by ventilators at intervals along the ridge in the case of a roof of the ridge type. The ventilators for a ridge roof to a machine shop were best provided with opening shutters so that the ventilation might be stopped in the winter or in driving rain or snow if required, or if preferred, exhaust ventilators could be used. In the case of a foundry it was usual to provide ventilators with continuous louvres for the whole length of the shop. These were best made of wood with a rebated fillet screwed on the back to stop rain or snow from driving in as far as possible.

The roof principals were best formed in steel of angles, tees, and other rolled sections. A steel principal offered less obstruction to the light and harboured less dust than a timber principal, and could generally be designed at very little greater cost, if any. One advantage claimed for timber roofing was that arrangements were more easily made for carrying shafting, &c., but this could be quite easily arranged for with steel principals, by forming the bottom tie of double angles or channels with sufficient space between to allow for the passage of a bolt. The line shafting could if required be carried directly from the principals and the counter-shafting carried from joists, channels, or planks as required by the circumstances of the case. For roofs of moderate span up to, say, 50ft., economical spacing might be taken as from 10ft. to 12ft., which allowed purlins of angle section to be employed. For roofs of larger spans it was frequently more economical to space the roof principals farther apart, and to use purlins of channel, zed, or rolled joist sections.

Dealing next with the stanchions and girders carrying the roof and gantries, these were, the author said, now commonly made of steel of various sections in place of cast iron as in the older shops. A steel stanchion could usually be designed more economically than one of cast iron, was not so liable to damage from blows, and attachments could more easily be arranged for girders to carry shafting, jib cranes, &c. Round cast-iron columns were sometimes used to carry the roofing of small spans for light machine shops, and light foundries where cranes were not required.

The gantry girders to carry the travelling cranes varied in type according to the span and load to be supported. The practice of the author was to take the whole of the load and crab, half the weight of the crane girders, and one wheel box, as coming on one gantry girder, and to use a working stress of six tons per square inch under ordinary circumstances. The depth of the girder should preferably be not less than $\frac{1}{15}$, and the lateral width not less than $\frac{1}{30}$ of the stanchion centres. Where the spans were large, or where the loads to be carried were great, it would probably be necessary to use a double-webbed girder, either of the plate or lattice type, to obtain greater lateral stiffness. In the case of light cranes it was often not possible to adhere to the proportions given above, owing to the comparatively light loads to be carried, and the proportions mentioned might to some extent be varied, say to $\frac{1}{20}$ and $\frac{1}{40}$ respectively, as the working stresses were usually considerably lower than the working stress of six tons per square inch given above. The crane rails should be of the bridge type, the weight being proportioned to the crane loads. Care must be taken that the girders were stiffly connected at the joints, and that they were stayed to the stanchions so as to prevent oscillation.

Where the shafting was carried from the crane girders, as was sometimes the case, the deflection and stiffness of the girders under load must be enquired into to ensure that the proper running of the shafting was not interfered with. The girders to carry the roofing varied in type according to the span and the load to be carried, as in the case of the gantry girders. Where the stanchions did not exceed 25ft. centres, a rolled steel joist would usually be of sufficient strength. The depth for a working stress of seven tons should not be less than $\frac{1}{18}$ of the span. For spans over 25ft. a lattice girder or plate girder would usually be required. One advantage of the use of lattice girders was that their increased depth fitted them to act efficiently as longitudinal stays or bracings to the lines of stanchions. The economical spacing of the stanchions was, of course, determined by the total cost of the stanchions and foundations and the girders carried by them, but this must also in many cases be affected by the spacing of the machinery.

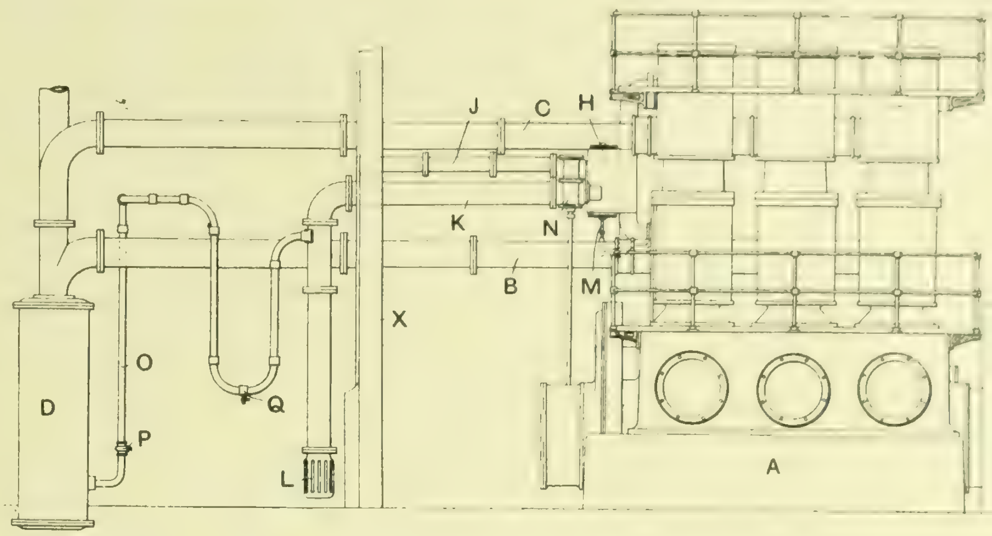
Complete buildings of the single storey type for engineering purposes had been constructed in America of reinforced concrete. Whilst, however, reinforced concrete might in some cases be a very suitable material for walls, it could not be considered as good as steel framing for the construction of stanchions, girders, and roof principals, owing to the greater bulk required and the consequent obstruction, and also owing to the difficulty of making suitable connections for shafting, supports, &c. For the internal construction of pattern stores and similar buildings, where fire resisting qualities were of the utmost importance, this material was eminently suitable.

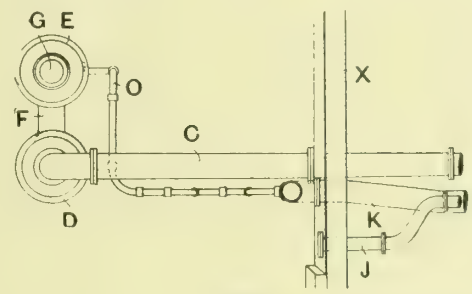
The floors of many of the older engineering shops were of flags, but the objections to this method of construction were apparent, and they were now generally made of concrete, either with or without a covering of timber. When the wearing surface was of concrete it should be finished with granite sand and cement, in equal proportions for the thickness of 1in. Concrete was not so suitable as wood for the wearing surface of a floor. It was almost impossible to ensure freedom from cracks in concrete over large areas, it was tiring to walk on, was dusty and liable to damage tools and fragile articles dropped upon it. If a wood floor was used it was usually laid on a foundation of cement concrete, from 4in. to 6in. in thickness, this being a variable dimension depending on the loads to be put upon the floor, and on the nature of the subsoil.

For floors where the work was of a heavy description the best floor surface was one of wood blocks 4in. deep, which might be formed by sawing off 3in. deals to lengths. To prevent damp from rising through the concrete the upper surface of the foundation should receive a coat of coal tar pitch about ¼in. thick applied hot, and the blocks should be dipped in the hot coal tar and bedded whilst the pitch was hot, any open joints being afterwards run in with pitch. Where the work was of a lighter character, the most satisfactory wearing surface was grooved and tongued maple planking, nailed either to 4in. by 3in. battens laid in the concrete or to planks laid transversely. The battens should be creosoted, or dipped in "jodelite" or "sideroleum," or some similar wood preservative, and the planking laid in hot tar. It was very important that the whole surface of the floor should be thoroughly tarred before the wood blocks or planking was laid, and that any wood blocks or pegs used for levelling purposes should be removed. Where the loads were very light and the foundation good, tar concrete might be substituted for the cement concrete, the upper surface being tarred as before.

INTERNAL-COMBUSTION ENGINES WORKING WITH COKE-OVEN GAS.

INTERNAL-COMBUSTION engines using coke-oven gas are liable to frequent pre-ignitions, due to the high hydrogen contents of the gas. To avoid pre-ignitions in such engines when using coke-oven or other gas or vapour containing a high percentage of hydrogen, Dr. Dugald Clerk, and the National Gas Engine Company, Ltd., Wellington Works, Ashton-under-Lyne, propose in a recent patent to introduce cooled exhaust gases to the charge inlet pipe, so that the oxygen contents of the entering air charge are reduced, and the nitrogen and carbonic acid contents increased. It has been found by experiment that by this means pre-ignitions can be entirely avoided without in any way reducing the power developed by the engine. Fig. 1 shows one arrangement applied to a six-cylinder vertical tandem engine, in which cooling of the exhaust gases is effected by an exposed pipe of considerable length. Fig. 2 illustrates a modification in which a water-cooled chamber is employed to cool the exhaust gases: in this figure the complete engine is not shown. Fig. 3 illustrates the application of a cooled chamber to the case of a horizontal gas engine.





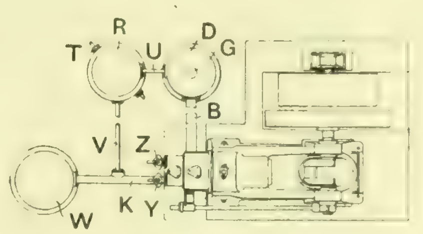


FIG. 1. FIG. 3.

INTERNAL-COMBUSTION ENGINES WORKING WITH COKE-OVEN GAS.

In the arrangement Fig. 1 the exhaust gases are led from the engine A by way of pipes B and C to the exhaust silencers D and E, which are connected in series by the pipe F,

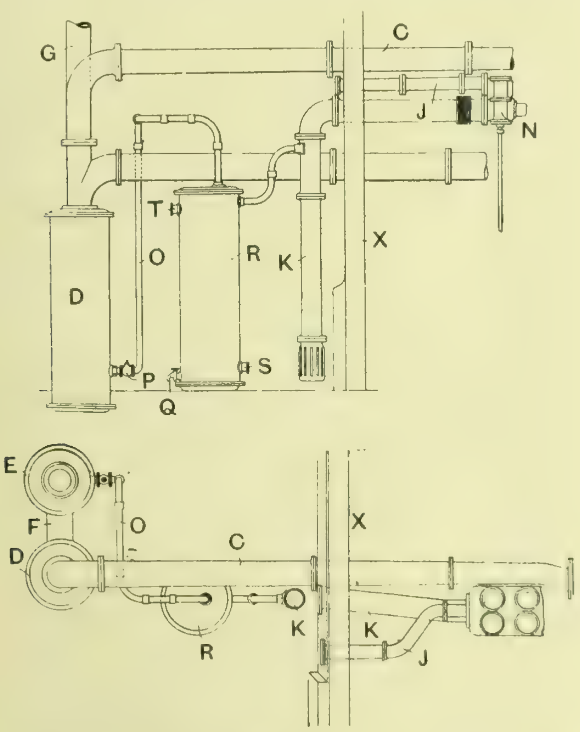


FIG. 2.

INTERNAL-COMBUSTION ENGINES WORKING WITH COKE-OVEN GAS.

the gases finally escaping by the upcast pipe G. The exhaust silencers are situated without the building in which the engine is housed; X represents the wall of the building. Gas and air are led to the mixing box H upon the engine by way of pipes J and K respectively, the air pipe K being provided with a protecting rose L. The conduits J and K are controlled by a regulating valve M and a governor valve N. From the bottom of the second silencing chamber E, a pipe O leads to a suitable point in the inlet pipe K. This pipe O is of considerable length, in order to present a large cooling surface to the surrounding atmosphere, and in order to render the arrangement compact the pipe may be bent into suitable outline, as shown in the drawings. A controlling cock P and suitable drain cock Q are provided in the pipe O. The dimensions of the pipe O and the adjustment of the cock P are such relatively to the dimensions of the air inlet pipe K that the proportion of exhaust gas in the air charge is about 10 per cent., although in some cases, in dealing with certain classes of gas, it is necessary to increase the proportion to 15 or 20 per cent. In the arrangement shown in Fig. 2, a chamber R, preferably water cooled, is included in the circuit of the exhaust gases passing from the silencer E to the air pipe K. Suitable water inlets and outlets S and T are provided upon the chamber R, and a drain cock Q is provided for the draining away of water condensed from the exhaust gases. In the arrangement Fig. 3, the exhaust gases are led by the pipe B to a silencer D. From the silencer D a pipe U leads to a chamber R, which may be water cooled. From the chamber R a pipe V leads to the air inlet pipe K. A suitable air suction silencer W may be applied to the end of the pipe K. The other end of the pipe K leads to the air-controlling cock Y. The action of this modification is similar to the action of the first described form.

It is to be noted that the cooled exhaust products are introduced at such a point in the air inlet pipe as will ensure that in passing through the inlet valve of the engine the exhaust products shall be thoroughly mixed with the air and gas constituting the remainder of the charge. This is essential in order that the oxygen content shall be uniformly reduced throughout the body of the charge in the engine cylinder.

The Junior Institution of Engineers.—A meeting of this institution will be held on the 12th inst., at 8 p.m., at the Institution of Electrical Engineers, Victoria Embankment, when a paper will be read on the subject of "Water-Heat Steam: The Effects of Heat upon Water, and a consideration of Water Movements in Steam Boilers," by Mr. Arthur Ross.

MODERN HIGH-SPEED GEARING.*

BY H. HUBERT THORNE.

EVERYONE who is connected with the engineering profession, either as a designer or as a user of machinery or power plant, must have been struck with the development which has taken place within a comparatively short time in gearing of various forms. Years ago, when really high speeds were unknown in practice, and accuracy was not an essential feature in most plants, it was deemed suitable to install cast gears with straight teeth, but, as requirements became more exacting, steps were taken to improve on these, and Dr. Hooke, noticing that with this type of gear smoother action always resulted when finer pitches were used, and realising that, on the other hand, the strength of the gear was reduced by decreasing the pitch, effected a compromise by using what he called "stepped teeth," in which the teeth were not straight across the face width, but arranged in sections so that each section was displaced by a fraction of the pitch in relation to the next section. This gear he claimed combined the smoothness of motion due to fine pitched teeth with the strength due to coarse pitched.

From the stepped gear to the single helical was an easy step; this type, however, offered the grave drawback that end thrust was set up in the gear, and to get over this, two single helicals of opposite hands were arranged side by side, thus forming the double helical. This type, whilst theoretically possessing advantages over the straight tooth, did not at first find favour with the majority of engineers on account of the indifferent manner in which it was manufactured, and even in a book published by an authority on design as late as 1895, the following appears: "Recently double helical gears have been adopted to avoid end-long pressure on the bearings caused by single helical teeth. They are machine moulded by two half patterns and work smoothly if well formed, being said to be stronger than ordinary teeth, which is doubtful." For some time after this, double helicals failed to make much headway, the reason being that considerable attention was paid to the accurate cutting of straight-cut gears, and these proved in many instances to be more reliable than badly moulded double helical gears. As, however, the demand for really high-speed gears became greater and greater, gear experts once more turned their attention to other forms of cut gearing which could be run at higher velocities without undue noise. One way out of the difficulty was found in the introduction of pinions built up of layers of raw hide, fibre, compressed paper or other similar materials, held together by metal end-plates, with rivets or bolts right through. For light powers, small ratios and particular drives, these undoubtedly offered advantages, and in some instances do still, but for general use they did not meet the demand for the following, amongst other, reasons: (1) Owing to the fact that rivets or bolts were necessary between the bore and the bottom of the teeth, only pinions of comparatively large diameter for the duties could be used. (2) Owing to the large diameter pinions, the wheels, with even moderate ratios, often became unduly large and expensive. (3) For large powers the blanks were difficult to obtain and very costly. (4) The strength of the gears being determined by that of the weakest member, viz., the pinion, the sizes of the wheels were very much in excess of strength requirements, and consequently they were unnecessarily costly and heavy. (5) The materials used for the pinions were usually adversely affected by atmospheric conditions.

Another system adopted by some was that of worm gearing, which certainly offered the advantages of quiet running and possibly high ratios, but against these had to be set the grave drawbacks that they could only be used for what we now hold to be moderate velocities, and, on account of the difficulties and expense of manufacture, small powers, and, further, that only when the ratio was very small could an efficiency greater than about 85 per cent. be maintained. The facts of the case being thus, certain firms determined that they would once more turn their attention to double helical gears, which, provided they could be accurately cut, would certainly overcome most of the objections to the other types. The result of their investigations was that two distinct types were evolved. These are now generally known as the "Staggered tooth" double helical and the "Continuous tooth" double helical. As a result of their introduction other types of gearing are being rapidly superseded for high speeds. Before considering the merits and demerits of the two types of double helical gears mentioned above, it will, perhaps, be as well to first consider what advantages they offer over straight teeth.

* Paper read before the Rugby Engineering Society, March 4th, 1913.

ADVANTAGES OF DOUBLE HELICAL OVER STRAIGHT TEETH.

(1) *Strength.* With straight cut gears the maximum bending stress on the driven tooth occurs when the driving tooth just engages with it at the extreme tip. As the tooth is straight,

FIG. 1.

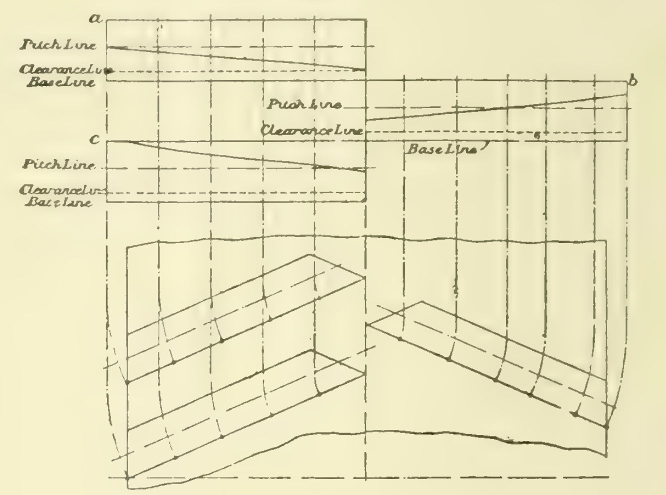


FIG. 2.

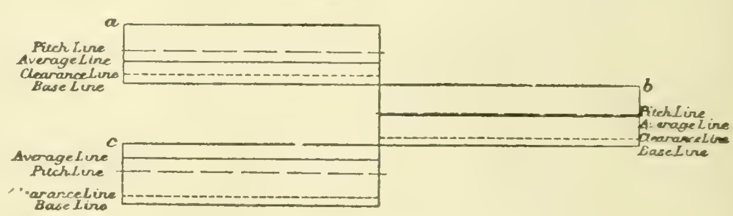


FIG. 3

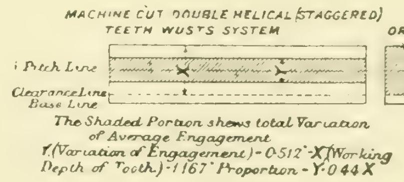


FIG. 4.

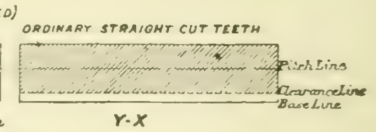


FIG. 5.

this stress is equal along its whole length. With double helicals the conditions are much better, as the maximum stress cannot occur along the whole length of the tooth at one time, engagement taking place at the extreme tip of a tooth at one point only, all other points in contact being between the extreme tip and a point below the pitch line. This is clearly seen in Fig. 1 to Fig. 5, which show the development of part of the rim of a staggered tooth double helical gear with three teeth in engagement at the same time. The elevation shows the lines of contact when the centre of the tooth *b* is in engagement at its pitch line. Fig. 3 shows the average engagement along each of the teeth, and Fig. 4 the total variation of average engagement. Fig. 5, on the other hand, shows the variation of actual engagement along the whole length of a straight tooth. By a comparison of Figs. 4 and 5, it will be seen that the variation of stress on the teeth is very much less with the double helical than with the straight cut teeth, and consequently the former is the stronger.

(2) *Smoothness of Running.*—It has been demonstrated by the exponents of the Stubb tooth, that rolling contact only takes place when teeth are in engagement at the pitch line, and that the further from this line the point of engagement is the more rubbing action results. Endeavours have been made with straight-cut gears to eliminate as far as possible this rubbing action by decreasing the depth of the teeth and increasing the pressure angle, but experience

has proved that very often, owing to the resultant decrease in the arc of contact, such gears have been not less, but more noisy than standard gears. With double helical gears, as the average engagement is spread over an area, the limits of which are comparatively near the pitch line, as seen in Fig. 4, the action becomes more nearly a purely rolling one, and the rubbing action, which must produce wear, is reduced to a minimum.

(3) *Absence of Vibration.*—Owing to the engagement being gradual in double helical gears, and not suddenly occurring along the whole length of the tip of the teeth, as in straight-cut gears, there is an entire absence of that distressing hammer action so often noticeable with the latter type, and, consequently much finer pitches can be adopted as they are not subjected to the same shocks and are moreover stronger.

(4) *Higher Efficiency*, due to elimination of losses caused by sliding friction. Where a single reduction double helical set is substituted for a double reduction straight-cut set, a saving of at least 5 per cent. in efficiency is effected.

(5) *Greater Ratios.*—As the root diameter of pinion necessary for strength, the capacity of the machine on which the wheel is to be cut, and the space available, are the only limiting factors, it is possible to supply gears with very large ratios, and many are running successfully with a ratio of 25 : 1.

RELATIVE MERITS OF STAGGERED AND CONTINUOUS TEETH.

In our previous consideration of double helical compared with straight-cut gears, we have, of course, assumed that all the types mentioned were cut correctly, and have ignored the defects due to inaccuracies in manufacture which must exist to a greater or a lesser extent in all types, but when we consider the different forms of double helicals, we must take into account, to some extent at all events, the processes of manufacture, as these play an important part in the accuracy of the production.

Staggered teeth are produced by means of gashed worms or hobs, the threads or teeth of which are so shaped that their section, in a plane at right angles to the axis of the wheel to be cut, is that of a straight-sided rack having the required pressure angle. These hobs, being machine relieved, can be ground without altering their cutting shape. Both wheel and pinion, being cut by the same hob to gear accurately with the same theoretical rack, are bound to gear together correctly, and as the hob itself has straight sides in one plane to correspond with the hypothetical rack, it can be produced with a degree of accuracy impossible with a shaped cutter.

Continuous teeth, on the other hand, are manufactured by means of end mills shaped to conform to the contour of tooth required. As the shapes of pinion and wheel teeth usually vary widely, it is necessary to use different end-mills for the two members of one pair of gears, and as these end-mills must be curved to suit the teeth to be cut, their accurate manufacture is a matter of some considerable difficulty. Moreover, these end-mills are necessarily small in diameter, being at the pitch line only approximately one half of the normal pitch to be cut, and, owing to their shape, they cannot be ground without altering the contour. Further, on account of size, and being subject to rapid wear, it is often necessary to use a number of tools in cutting one wheel, and as a consequence variations in thickness or shapes of teeth may result.

Before the end-mills can be manufactured, considerable difficulties have to be overcome in the determination of their correct shapes, which should be such that the contour of the cut teeth, above the base circle, in a plane at right angles to the axis of the gear to be cut, is a true involute. That the end-mill itself should not be of involute shape is obvious, but the actual shape required is complicated by the fact that a shaped cutter will not cut its own shape in a spiral groove.

When considering the actual cutting processes, other advantages of staggered over the continuous teeth are at once apparent, for whilst the latter call for step by step division with its inherent defects, the former are produced by one continuous process, the hob being fed across the face of the wheel as both hob and wheel revolve at constant speeds.

Where comparatively small gears are required, the staggered tooth again shows its superiority, as it is impossible to produce on a commercial basis a continuous tooth gear having a pitch much finer than 1in., on account of the very small diameter cutters which would be necessary, whilst with hobbed double helicals the cutters or hobs can be made to cut any pitch down to 14 D.P., or even less.

One advantage claimed for the continuous tooth is that it is stronger, but as modern gears are dimensioned with a view to wear, and are always overstrong, this is not of practical importance, and is, moreover, discounted by the fact that whilst the staggered tooth offers even resistance to bending along its whole length, the continuous tooth, being stiffer in the middle, offers uneven resistance, and consequently is liable to wear unevenly.

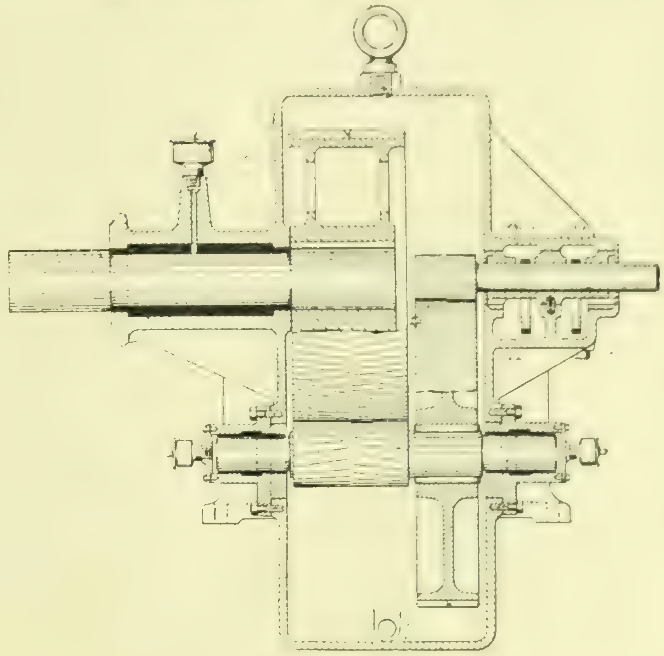


FIG. 6

PRACTICAL CONSIDERATIONS IN THE DESIGN OF DOUBLE HELICAL GEARS.

There is one point in connection with the determination of the sizes of double helical gears which cannot be too strongly emphasized, and that is: the proportions should be controlled entirely by consideration of wear. If this is done the actual strength of the gears will be well on the right side.

Materials.—For general purposes a forged steel pinion containing about 4 per cent. carbon, and a cast-iron wheel, are to be recommended, but where the tooth pressure will be heavy or the gear subject to shock, cast steel wheels should be used, and it may be necessary, particularly where the velocities are high, to resort to alloyed steel pinions, but these cases can only be dealt with on their merits by the specialist.

Diameters and Face Widths.—The following facts must be borne in mind:—(1) Small diameter gears will, if properly designed, run more silently than larger ones, therefore low velocities should be aimed at. (2) The number of teeth in engagement can always be increased by widening the face width of the gear. (3) Pinions can be made of smaller diameter and greater face width when supported on both sides than when overhung on a shaft end. The limiting factor in the diameter of the pinion is usually the minimum diameter permissible at the root of teeth, to ensure sufficient strength and rigidity in the driving shaft.

Where the teeth are cut solid on the shaft, this diameter need be only slightly greater than the necessary diameter of the shaft itself, but where a sleeve pinion is to be employed sufficient metal must be allowed between the bore and the root of the teeth to properly support the teeth after the necessary keyways have been cut. With fine pitches such as are adopted with staggered tooth gears, the permissible minimum diameter is much less than with continuous tooth gears, and by increasing the face width the increased pressure thus involved can be provided for.

The maximum ratio obtainable depends then, not on the minimum number of teeth advisable in the pinion, which can

be anything within reason owing to the fact that continuity of engagement is ensured by face width, but by the minimum diameter of pinion from considerations mentioned above, and the maximum diameter of wheel which can be accommodated, or where this is not limited, by the largest wheel which the manufacturers can cut. This means, of course, that very much larger ratios can be accommodated with double helical than with straight-cut gears, and consequently it frequently happens that for a double reduction straight cut set, can be substituted a single reduction double helical set, which means an economy in space, increased efficiency, and sometimes even a saving in cost. Ratios up to 25 : 1 in a single reduction have been frequently made, and have been running for lengthy periods to the entire satisfaction of the users.

Wear. Emphasis has been laid on the necessity to dimension gears for wear, and in this connection it is interesting and necessary to note that for a given diameter of gear the involute curve is always the same whatever the pitch, the radius of the curve at the pitch line being for a given angle of pressure a definite proportion of that diameter, and, further, that the flatter the curve of a tooth the more able it is to resist wear. From these facts it follows that the pitch of a tooth can be reduced without decreasing its wearing properties, providing the tooth itself is strong enough to resist bending, and, further, that the larger the diameters the better the wearing properties. Acting on these facts the manufacturers of the staggered tooth gears introduced considerably finer pitches than had hitherto been used (these gears have met with marked success), and in addition in determining the permissible pressure on any tooth per inch of its width, due allowance is always made by them for the diameters of the mating gears.

Mounting Gears.—It is essential to the proper running of double helical gears that they should be well and truly mounted on shafts of sufficient stiffness running in bearings of ample dimensions, rigidly supported. Wherever possible both pinion and wheel should be supported by a bearing on each side close up to the boss. Where the velocities are above 1,200ft. per minute it is always advisable to totally enclose the gears, and run them in oil, and where the velocities are very high, the oil should be squirted under pressure along the face of the gear near the line of engagement. In these cases it is also necessary to provide forced lubrication for the bearings. Having now briefly discussed the general question of double helical gears, it will perhaps be as well to consider some general applications.

Machine Tools.—For machine tool drives the introduction of high-speed steel has created a demand for high-velocity gears which will work quietly and without vibration, and which will transmit power at a uniform velocity. These conditions can only be met by providing continuous engagement, for which double helical gears are essential. To allow reasonable overlapping of the teeth, staggered tooth gears with an angle of 23° should preferably have a face width of six times the pitch, but on account of the comparatively fine pitches which can be adopted, this does not necessarily involve excessive face widths.

Air Pumps for Condensing Plants.—Owing to the unequal torque always existing with this type of drive, straight-cut gearing has proved unsatisfactory, as it is necessary to ensure continuous engagement. Double helical gears should be used of ample size, the wheels having heavy rims, and both pinion and wheel should be mounted as rigidly, and set as truly, as possible. These latter points are very essential as with the slightest play between the pinion and the wheel teeth, the uneven torque will cause vibration to be set up, and a ringing noise will result. The best arrangement where the wheel is mounted on the pump shaft supported by the pump frame, is to mount the pinion on a short length of shaft carried by two bearings on the casing, this shaft being connected to the motor by means of a flexible coupling.

High-speed Centrifugal Pumps. These pumps frequently run at speeds for which electric motors cannot be readily obtained, and so some speed-increasing device must be introduced. As the speed of the driven shaft is already high, it is essential to keep the pitch diameter of the pinion as small as possible, as otherwise the pitch line velocity of the gear may become excessive. Double helical gears of small pitch and comparatively wide face width offer the best solution of the problem, and these should be totally enclosed and run in an oil bath, the shafts being supported by self-oiling bearings of ample dimensions to ensure steady running with little attention.

Large Power Pumps.—Double helical gears are most suitable for this class of drive, as they allow for large ratios in a single reduction, and also provide that continuity of engagement which, owing to the variations in torque which must occur on the wheel shafts, is absolutely essential if the gears are to run smoothly and without vibration. It is a well-known fact that a continued hammer action will very quickly cause distress and failure in material which would be quite capable of withstanding much heavier loads when applied without shock. With straight-cut gears a shock is often noticed as the teeth come into engagement, even when the load is fairly steady, but with a fluctuating load such as that under consideration, the advantage to be derived from the continuity of engagement of double helical gears is at once apparent, as it not only lessens noise, but also considerably lengthens the life of the gear.

Collieries and Mines. The requirements of the above are most exacting. The gears used often have to run for long periods, the loads are usually heavy and shocks and overloads are necessarily frequent. Added to these facts are the ones that very often the shafts to be driven are required to run at comparatively low speeds, and that the motors, which are now so often the prime movers, must run at relatively high speeds (if they are to work economically), which means, of course, that large reductions must be employed. Still again, the space available is often limited. To meet these conditions, no other type of gear at present known can successfully compete against the double helical. Reductions up to 25 : 1 can often be arranged in a single set without in any way affecting the running of the gears, if properly designed. That these ratios cannot be arranged with straight-cut gears is due to the fact that the smaller the number of teeth in the pinion of a straight-cut set the more pronounced becomes the shock resulting from the sudden entering and leaving contact of the teeth along their full face width. Then, where shocks and overloads are to be withstood, the load can be distributed over as many teeth as is thought desirable by merely increasing the face width, and where space is limited, the centres can be reduced to the smallest practicable in view of the requisite high speed shaft diameter and ratio of reduction required, and the necessary bearing surface obtained on the teeth by proper choice of face width.

For coal screening plant, elevators and conveyers, which generally run in dust-laden atmospheres, the gears must be enclosed, and here again the advantages of the double helical type are pronounced, as, owing to the fact that a very small number of teeth can be chosen for the pinions, and the teeth themselves cut solid on their shafts, the size and weight of the casings can be reduced to a minimum, and at the same time a double reduction gear can be arranged, giving a total ratio up to 60 : 1 with the driving and the driven shafts in line. Such gears are now standardised, and can be seen at work on a large variety of drives. Fig. 6 shows a section of such a gear.

Rolling Mill Gears. The conditions under which these drives are required to work are, perhaps, more onerous than for any other class of drive usually met with. The overloads are exceedingly heavy, frequent, and often difficult to accurately determine, the surroundings are dirty, and the attention likely to be paid to them very meagre, and such as there is, often unskilled. One of the first essentials to a successful rolling mill is continuous engagement, which can alone be procured by the adoption of double-helical teeth, and without which it is impossible to reasonably withstand the great shocks incidental to these drives. Having determined the sizes of the gears, it is very necessary to see that all shafts and bearings are of very ample dimensions, and that the whole arrangement is truly and rigidly mounted. Too much attention cannot be paid to the mounting of such gears, as so much depends on the freedom from vibration of such a plant. The gears should, where practicable, be encased and run in oil. It was for long the custom to provide heavy flywheels on the rolling mill shafts to supply the sudden demands for energy when rolling, but it has been found that an arrange-

ment can be adopted which takes up very much less space and which proves very often to effect a saving in first cost. This is by providing a high velocity cast-steel flywheel on the high-speed side. This means, of course, that the gears must be designed to transmit the full power given out by the flywheel, and consequently that they must be considerably larger than they otherwise need be, but when it is remembered that the energy of a flywheel varies as the square of its velocity at the diameter of gyration, and that consequently with a ratio of only 9 to 1, if the diameter of the high-speed pulley is one-third the diameter of the low-speed, the velocity will be three times as great, and the weight need only be one-ninth for the same energy. Owing to this fact, it sometimes happens that the saving in the reduced cost of the flywheel alone more than pays for the gears.

Whilst dealing with the rolling mill drives, it will be interesting to notice an arrangement which has recently been patented (Wiesengrund and Power Plant Company, Ltd., Patent) for combining driving, starting, and roll turning gear electrically operated cold rolls. It forms a self-contained unit which has only to be coupled to the motor and mill respectively. The total reduction from motor to working speed of rolls is obtained in a single reduction of double helical gears, which may be anything up to 15:1, thus providing highest efficiency with greatest simplicity. The main motor is used for starting the rolls through a back gear, which reduces the roll speed so far that the normal torque is amply sufficient for starting. When the through drive is put into operation, the back gear automatically disengages. The back gear also gives the necessary speed reduction for roll turning. Fig. 7 clearly shows the arrangement.

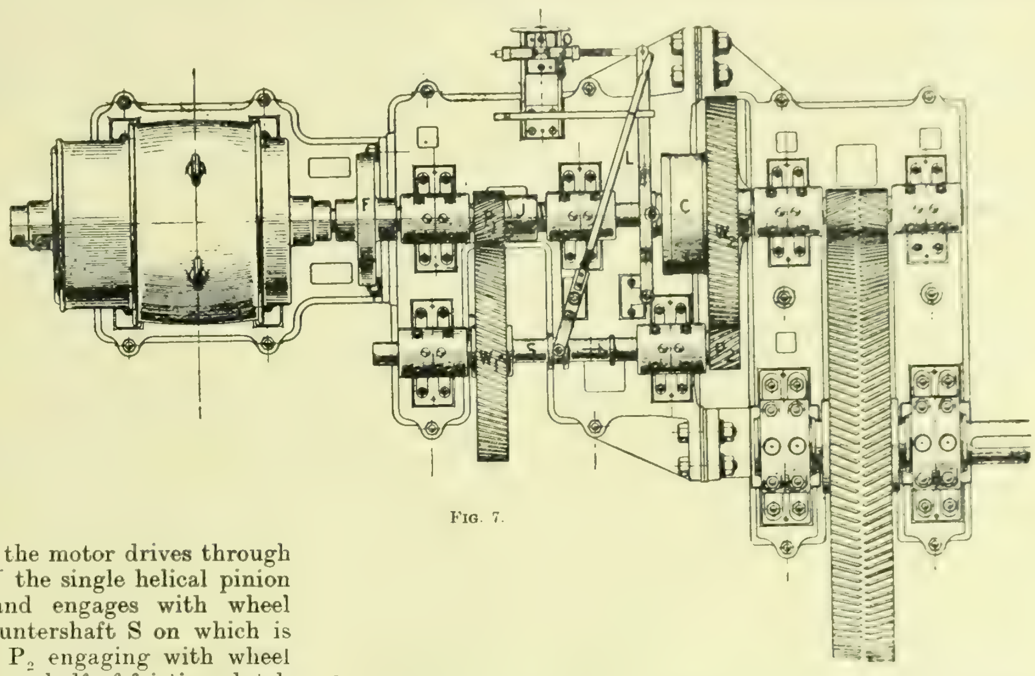


FIG. 7.

When the plant is to be started, the motor drives through flexible coupling F and jaw clutch J the single helical pinion P_1, which is loose on its shaft, and engages with wheel W_1, which latter is mounted on countershaft S on which is also fastened single helical pinion P_2 engaging with wheel W_2. Wheel W_2 is bolted to the driven half of friction clutch C mounted on the shaft end of the main driving pinion, which latter engages with the main wheel. The driving half of the friction clutch C is mounted on the same shaft as jaw clutch J and pinion P_1, but when starting the friction clutch is in the "off" position, so that the drive goes through the back gear. When the motor has reached full speed clutch C is slowly engaged by means of operating mechanism O, so taking the drive direct from the motor to main pinion P_3. Wheel W_2 is thereby accelerated, and the thrust in the two trains of single helical gears reversed, which causes the shaft S to slide in the direction of the arrow, in which it is free to move, until the two trains of the back gear are out of engagement. If the disengagement does not take place fast enough, pinion P_1 is accelerated and runs away from the driving jaws of the jaw clutch, pressing this back against the spring, clearly shown in the drawing. This arrangement excludes the possibility of failure of the automatic action of the backshaft causing any damage. When the plant is at a standstill the clutch C is disconnected, and shaft S returned into its starting position by means of lever L. For roll turning the drive goes continuously through the back gear, clutch C remaining disengaged.

Turbine Gears.—If any further proof were needed of the superiority of double helical over straight-cut gears for really high velocities, it is to be found in the fact that when the De Laval turbine was introduced and straight-cut gears were fitted, they proved to be absolutely useless, and the author understands, on very reliable authority, that design and cut these how they would, the pinion teeth stripped in from two or three days. Only when double helicals were substituted could the inventor obtain gears which would stand up to the work. It is surely a striking testimony to the genius of M. de Laval that so many years ago when cut double helical gears were practically unknown, he should have introduced some of such fine pitches that even to-day their manufacture with a sufficient degree of accuracy is a matter of considerable difficulty, and not only introduced but successfully employed them. Although he was not of the same nationality as most of us, we are ever ready to acknowledge our indebtedness to men of such outstanding ability, and deplore the loss which his country, and the world at large sustained by his recent death.

Since helical gears were first introduced for turbine drives, the demands have considerably altered; then, comparatively small powers and extremely high turbine speeds were the order of the day; now, the powers to be transmitted have increased and generally speaking the speeds have decreased, but certain conditions must be fulfilled, amongst which are the following:—

Distribution of Load.—With straight-cut gears, once the number of teeth, diameter and pressure angle are determined, the engagement conditions cannot be altered however much the face width is increased. If, for example, two teeth are in engagement with a particular combination having a face width of four inches, there will still be only two teeth in engagement if the face width is increased to 40in. With double helicals, on the other hand, the engagement conditions depend not only on the factors mentioned above, but also on the face width. By suitably increasing the face width the load can be distributed over any number of teeth required.

Constant Angular Velocity.—As already explained, when dealing with double helical gears in general, the average engagement takes place within a comparatively small area above and below the pitch line, and, as a result, a more truly rolling action is obtained, and the sliding friction inseparable from straight-cut gears is minimised.

Low Velocity.—It is an established fact that the lower the velocity of a gear the easier it is to produce so that it will run quietly and without vibration. With double helical gears the minimum diameter of the pinion, and consequently the velocity of the gear, is only limited by the diameter of shaft requisite for the duty. By increasing the face width, the load can be reduced per unit of length of face to any desired figure.

Permissible Torsion.—Another very important point in connection with turbine gear pinions is that of torsion. Where the diameter of a pinion is small, and the face width great, the amount of torsion may be considerable, especially so where a central bearing is used. To get over this difficulty there was introduced some little time ago a new arrangement (Wiesengrund and Roberts' Patent), in which the power is transmitted to each end of the pinion from the centre. To allow for this the pinion shafts are made hollow, and the

power transmitted to a central coupling by means of an inner shaft, the torsion on which does not in any way affect the teeth themselves.

Lubrication and Mounting.—Space does not permit us to go into these questions in the way they deserve, but it can be taken that the general practice is to squirt oil under pressure at or near the line of engagement, and to provide forced lubrication for the bearings also. The gears themselves should be rigidly mounted and set with extreme accuracy, or otherwise vibration will be set up.

THE SOCIETY OF ENGINEERS: PRESIDENTIAL ADDRESS.

MR. ARTHUR VALON, A.M.Inst.C.E., delivered his inaugural address as President of the Society of Engineers (Incorporated) on March 3rd, and made reference to a number of questions affecting the engineering profession. He pointed out that the inventive ingenuity and scientific knowledge brought to bear upon the smallest details of engineering work increased the number of practicable solutions to any given problem, and engineers were therefore obliged to specialise. So far as specialisation led to economy, due to division of labour, it was advantageous, but rigid specialisation was detrimental both to the engineer and the community. Whatever position an engineer occupied, he must know his work thoroughly, and the range of his studies must be restricted on that account, but should not be limited by want of organisation and co-ordination of existing knowledge. Standardisation was one method of effecting co-ordination, but there was a danger that a standard might be regarded as a petrified convention instead of merely the best summary of existing knowledge. The advantages of standardisation, however, far outweighed its risks, by effecting economies and setting energy free to deal with newer problems. The work of the Engineering Standards Committee was referred to in this connection.

The development of engineering during the past 20 years had wrought a great change in the personnel of the profession. When engineering was almost entirely a matter of practical experience, professional qualification was independent of general education, but now that rational methods of calculation and design had superseded those of empiricism, a complete knowledge of these principles was necessary to every engineer, so that the system of apprenticeship no longer completely met educational requirements. The requirements for modern engineering training were contrasted with those of 20 years ago, and it was shown that a great increase had taken place in the number of engineers occupying more or less subordinate positions, for which technical competence was a greater recommendation than personal initiative.

Speaking of the organisation of the profession, Mr. Valon said that the numerous engineering societies had confined their work almost exclusively to educational matters, and but little attempt had been made to use the corporate strength of the profession to improve the status of engineers. The material interests of a professional man might be classified under employment, its remuneration and its conditions. The difficulties of readily obtaining suitable employment (and conversely of easily securing competent assistants) was mentioned, and it was urged that a central organisation for dealing with appointments would be not only a great convenience but a source of strength to the profession, as it would then be possible to issue warnings against appointments carrying unsatisfactory conditions.

With regard to statutory registration, it was only right that those who had spent time, energy, and money in qualifying as engineers should be in a better position than those who had not done so, but before registration could be enforced there were many obstacles to be surmounted, which could be overcome only if the profession were united in desiring statutory recognition, and took steps to present their views in the proper quarter, through a suitable organisation. The British Medical Association supplied an example of an organisation effectively presenting the views of the rank and file of their profession, who would otherwise have been obliged to submit to legislation that they believed to be inimical to their best interests. It was essential, however, that such an organisation should be merely protective and not aggressive.

Engineering had an æsthetic side of hardly less importance than its utilitarian aspect. Many of the structures for which they were responsible were prominent and conspicuous objects, in which beauty was a desideratum, but differences arose when they came to define what was or was not beautiful. They must adapt available means to the practical end in view, and in so doing they should endeavour to obtain beauty of line, of form, and of colour, but the ultimate verdict on their efforts would be given by posterity. The destruction of a countryside and the development of unbeautiful urban centres, as the effect of industrial operations, would meet with an unfavourable verdict, but if this was a crime it was one in which all had shared, and the responsibility did not lie entirely, or evenly chiefly, with engineers. Hitherto engineering science had been directed almost exclusively to economic ends, but it was not unlikely that in the future it would be applied more directly for ameliorating social conditions and ensuring a proper standard of civilised life to every member of the community.

CITY PASSENGER TRANSPORTATION IN THE UNITED STATES.*

BY GEORGE DUNCAN SNYDER, M.INST.C.E.

THIS paper treats of city passenger-transportation lines other than tramways and the city portion of through railways. The cities in the United States having such lines, and their metropolitan populations in 1910, are: New York 6,474,568, Chicago 2,446,921, Philadelphia 1,972,392, Boston 1,520,420.

New York.—The first tramway was worked in 1832 and the first omnibus-line in 1835. The first elevated railway was worked in 1871, and was followed by lines in Brooklyn and Jersey City. The first underground railway was opened October 27th, 1904. The city is constructing new lines and has about concluded agreements for the operation of a dual transportation system by the Interborough Rapid Transit Company, who operate the present subway, and the Brooklyn Rapid Transit Company. The Hudson River tunnels were first worked February 26th, 1908. A tramway tunnel has been built across the East River at 42nd Street, but has not yet been worked. New York has 133·17 miles of transit-lines, and 95 miles under construction.

Chicago.—The first elevated railway, the Southside line, was opened on June 6th, 1892, using steam locomotives. This was followed by lines to the west and north-west, which were later connected together by the Union loop in the centre of the city. The motive power was changed to electricity between 1896 and 1898. The length of these lines aggregate 74·56 miles. The municipality now proposes to construct a system of underground railways, 56 miles long, at an estimated cost of $96,257,000, the equipment of which will cost $34,844,000 more.

Boston.—The Tremont Street subway for tram-lines was opened on September 1st, 1897, and was followed by the elevated railway on Atlantic Avenue in 1901. A tunnel crossing the harbour to East Boston, for tram-lines, was opened in 1904. The Washington Street subway for trains of the elevated system was opened on November 30th, 1908. The elevated railway was extended to Forest Hills in 1909. The Cambridge subway was completed in 1912, and the East Cambridge elevated tram-line in the same year. Surface, elevated, and underground lines are under one management, and passengers are permitted to transfer from one to the other without payment of extra fare. The existing lines are 24·48 miles long, and 6·88 miles are under construction.

Philadelphia.—Philadelphia has a combined underground and elevated system 7·41 miles long, and a line on private right of way 17 miles long.

Construction and Working.—There are 250 miles of high-speed city transit-lines in the United States, and 174 miles proposed or under construction. Such lines are either built for multiple-unit trains, for tram-lines, or to cross obstacles to continuous transit, such as rivers, mountain, &c. Physically they are built under streets, over streets, or elevated or depressed on purchased land. Elevated lines are preferred from the standpoint of passengers, while underground lines are less of an obstruction to streets and less damaging to the adjoining property. New York and Chicago have 3 and 4-track lines for the operation of low and high-speed trains, while Philadelphia has a 4-track line with trains and tramways, and Boston's 4-track line is used entirely by tramways.

* Abstract of paper read before the Institution of Civil Engineers, March 4th, 1913.

Stations. A single platform between tracks is the cheaper to operate. Four-track lines have express station platforms between local and express tracks, and side platforms at local stations. At the terminus at Brooklyn Bridge 35,000 passengers per hour are dealt with.

Shallow versus Deep Level. Practically all underground railway are of the shallow type. The 4-track line on Lexington Avenue (New York) is being constructed with local tracks near the surface and express tracks tunnelled at a deep level. Deep-level lines cause less inconvenience during construction, but are more expensive to work on account of the necessity for lifts.

Typical Sections.—The internal height varies from 13ft. 2in. to 15ft. 4in., and the width for a single track from 11ft. 6in. to 13ft. 2in. The construction for shallow subways is either of steel beams in roof and sides, embedded in concrete, or of reinforced concrete.

Methods of Construction. Construction is carried on under a temporary wooden flooring for the street. A portion of the Brooklyn subway was excavated with a steam shovel. The depth of the subways necessitates the underpinning of adjoining building foundations and the temporary support of the elevated railway. Subway lining is of concrete, excepting the iron-lined subaqueous tunnels. Rock tunnels are driven with a top heading. Roof shields have been successfully used in soft ground in Boston. Subaqueous tunnels are usually driven with shields and compressed air, and lined with cast iron. The East Boston tunnel was driven with a roof shield and lined with concrete.

Ventilation.—In shallow subways ventilation is effected by exhaust fans between stations. The Hudson and Manhattan Railroad use exhaust fans assisted by the piston action of the trains.

Elevated Railways.—On narrow streets the elevated columns are placed in the footwalk and on wide streets in the carriage-way. The increase in loads since the first lines were built has necessitated their strengthening or rebuilding. Present practice is to use riveted plate girders. Since 1893 steel has been used instead of iron. Double-track structures weigh 900lbs. to 1,600lbs. per lineal foot. Solid concrete floors, with ballaster tracks, have been used on recent structures. Lines on private right of way are built in suburbs, and are elevated or depressed to avoid level crossings with streets.

Bridges.—The great bridges over the East River now form part of through transit-routes, which avoids the terminus problem which existed when they were worked independently.

Length of Trains.—The length of trains has increased from three cars on the first elevated to ten cars in the New York subway, and still longer trains have been suggested.

Density of Traffic.—The density of traffic on the New York subway is 4,000,000 passengers per mile of track per annum. The peak load on most lines is between 5 and 6 p.m., and amounts to about 15 per cent. of the total for the day. Monday generally has the maximum traffic for the week, amounting to about 17 per cent., and Sunday the minimum—about 9 per cent. About 7 per cent. of the annual traffic is carried in July and 9 per cent. in December.

The Riding Habit.—The number of passengers per annum is increasing as the square of the population. New York had 43 passengers per head of population in 1860 and 322 in 1910, and if the present rate of increase is maintained in the future, this will amount to 913 in 1950.

Fares.—The fare is almost universally 5 cents regardless of the distance, although much dissatisfaction with this arbitrary rate exists among managers.

Cars.—New cars are being made of steel, and the tendency is to increase the size, the most recent being 70ft. long, 9ft. 6in. wide, and 12ft. 6in. high, weighing from 86,000lbs. to 120,000lbs.

Permanent Way, &c.—Underground lines use "T" rails on wooden sleepers, laid in crushed stone. In Philadelphia the rail is attached to short wooden blocks, fastened to a steel box girder embedded in concrete. The maximum gradients are from 1 in 33 to 1 in 12·5, and the maximum radii of curves from 90ft. to 150ft.

Signals and Interlocking.—Automatic block signals are not used on the older elevated lines nor on the local tracks of the New York subway except at special points. They are used on express tracks in New York and Chicago, and for multiple unit trains in Boston and Philadelphia. A headway of 90 seconds can be maintained with automatic block signals with a speed of 40 miles per hour. A headway of 20 seconds has been maintained without signals and with low speed.

Methods of Working.—Four-track lines are worked with express trains on one pair of tracks, and local trains or train lines on the other. On 3-track lines express trains are run in one direction in the morning and in the other in the evening.

Franchise Conditions.—The earlier lines were built with private capital under perpetual franchises, but the municipalities are now building the lines and leasing the right to work them for a term of years.

Cost.—Underground lines cost \$835,000 to \$4,000,000 per mile of track, and elevated lines \$200,000 to \$600,000 per mile of track—without equipment. In New York City earth excavation cost \$2·90 to \$6·25 per cubic yard and rock excavation cost \$4 to \$12; tunnelling \$8·25 to \$9·50 per cubic yard; concrete \$8 to \$11 per cubic yard.

Cost of Working.—The cost of working varies from 44 per cent. to 70 per cent. of the gross receipts. The cost per car mile is 9½ cents to 20 cents.

Conclusion.—Exclusive transit-lines have only been built in cities of about 1,000,000 inhabitants, but may prove profitable in smaller cities where the riding habit of the population is pronounced.

INSTITUTION OF NAVAL ARCHITECTS.

THE spring meeting of this institution will be held in the hall of the Royal Society of Arts, John Street, Adelphi, on March 12th, 13th, and 14th. The following is the programme of proceedings. Wednesday, March 12th, morning meeting, at 11-30 o'clock, (1) annual report of Council; (2) Election of the President, Officers and Council; (3) Election of new members, associate members, associates, and students; (4) Appointment of scrutineers for the next annual meeting; (5) Address by the President; (6) Presentation of the Institution Gold Medal and Premiums. The following papers will then be read and discussed: "Recent Developments in Battle-ship Type," by Alan H. Burgoyne. "The Influence of Air-pumps on the Military Efficiency of Turbine-engined Warships," by D. B. Morison. Thursday, March 13th, morning meeting, at 11-30 o'clock, "Mechanical Gearing for the Propulsion of Ships," by the Hon. Sir Charles A. Parsons, "Compressed Air for Working Auxiliaries in Ships Propelled by Internal-combustion Engines," by W. Reavell, "The Energy Systems accompanying the Motion of Bodies through Air and Water," by Professor J. B. Henderson. Evening meeting, at 7-30 o'clock, "The Calculation of Stability in Non-intact Conditions," by Prof. W. S. Abell. "Notes on Modern Airship Construction," by Baron A. Roenne, "The Longitudinal Stability of Skimmers and Hydro-aeroplanes," by J. E. Steele. Friday, March 14th, morning meeting, at 11-30 o'clock, "On Large Deck Houses," by J. Foster King, "Methodical Experiments with Mercantile Ship Forms," by G. S. Baker, "Launching Declivities for Ships, and their Influence upon Poppet and Way end Pressures," by A. Hiley. Evening meeting, at 7-30 o'clock, "Stresses in Stayed Cylindrical Shells," by C. E. Stromeyer, "The Distribution of Stress due to a Rivet in a Plate," by Prof. E. G. Coker, and W. A. Scoble, "Stresses in a Plate due to the Presence of Cracks and Sharp Corners," by C. E. Inglis. The annual dinner of the Institution will be held on Wednesday, March 12th, at 7-30 p.m., in the Grand Hall of the Connaught Rooms.

Personal. — Dr. A. R. Forsyth, M.A., D.Sc., LL.D., F.R.S., formerly Sadlerian Professor of Pure Mathematics at Cambridge, has been appointed Chief Professor of Mathematics in the Imperial College of Science and Technology, South Kensington. His organising and administrative ability has been less clearly demonstrated in the part that he has played upon numerous boards and committees at Cambridge. He will have full scope for the exercise of this side of his activities in giving form and effect to the new policy framed by the governing body of the imperial college, by which it is intended to revise and raise the standard of the whole of the mathematical teaching, and to bring it into closer relation with the other departments of applied science in the college.

ELEMENTARY PRINCIPLES IN STEAM TURBINE DESIGN.*

By H. T. Herr.

Like the steam and gas engine, the turbine is a machine for obtaining mechanical work from heat energy. A full conception, therefore, of its underlying principles requires a knowledge of pure and applied thermodynamics, as well as familiarity with mechanics and experience in machine design and construction. The turbine converts the heat energy of a gas into useful mechanical work by transforming such heat energy into velocity and then extracting the energy in such

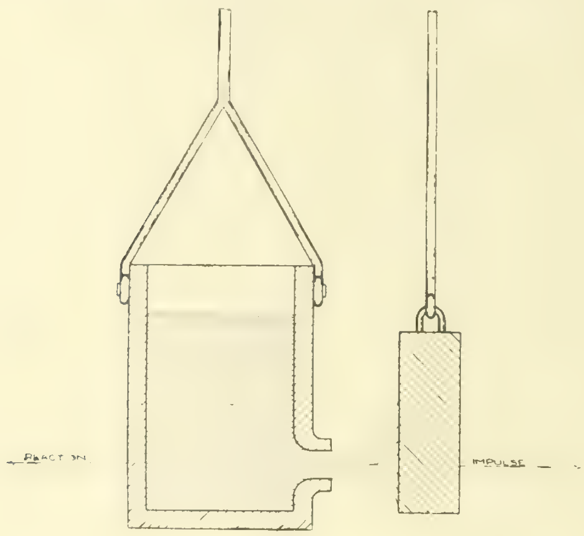


Fig. 1.

velocity by means of the rotation of a spindle, caused by the impulse and reaction of jets of steam on suitably-designed blades or vanes.

All commercial types of turbines—steam, water, or gas—are divided into two general classes, viz., (1) impulse and (2) reaction. Strictly speaking, all steam turbines use both impulse and reaction in their operation, as the blades of the rotor are moved by the impulse and reaction of impinging

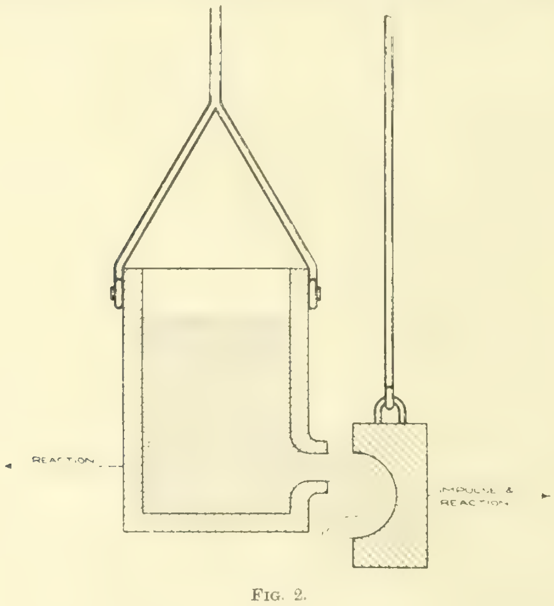


Fig. 2.

jets of steam issuing from nozzles or passages essentially equivalent to nozzles.

Fig. 1 illustrates the impulse of a jet of water issuing from a vessel and impinging upon a flat board hinged opposite. As the result of the force of the jet, the board will obviously move to the right. As the jet issues from the vessel it exerts a reaction on the tank, tending to move it to the left. Fig. 2 is intended to illustrate the significance of impulse and reaction as they are used in turbine practice. In this case water from a vessel impinges against the curved surface, as shown in the illustration, and before it leaves this surface is turned back through an angle of 180°. The board is therefore acted on by two forces simultaneously, both tending to move it to the right. The jet striking the board creates an impulse, and, when leaving the board, a reaction, both of which are equal and in the same direction, frictional losses neglected. If the jets in Figs. 1 and 2 have the same velocity and density, with friction neglected, the pressure on the block in Fig. 2 will be twice that on the block in Fig. 1.

Fig. 3 illustrates a nozzle and blade wheel in which the blades have a single curvature, *i.e.*, the steam in its passage

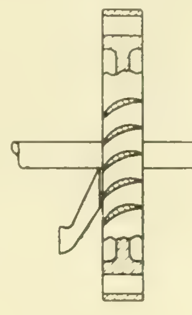


Fig. 3.

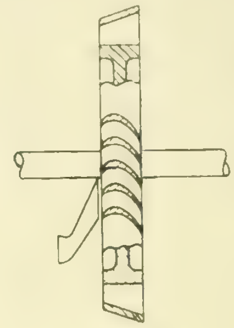


Fig. 4.

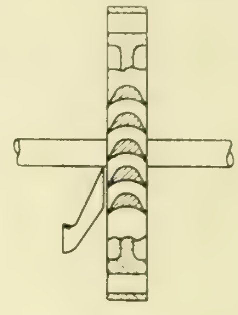


Fig. 5.

through the blades is not turned back on itself. If this wheel were held stationary the steam would leave the blades in a direction nearly parallel to the shaft. The only force, therefore, effective for moving the blades is the impulse of the jet. Fig. 4 indicates a blade wheel and nozzle in which steam from the nozzle enters the blades in a direction parallel to the axis, the jet then being turned backward through an angle less than 90°. On leaving the blades the jet exerts a reaction on the wheel, which, if held stationary, would be felt as a force tending to turn it. Fig. 5 shows blades with nearly 180° curvature, which turn the steam back on itself on leaving the blades. The wheel would therefore be moved first by the impulse of the jet, and then by its reaction.

When steam expands through an orifice or passage it acquires a velocity proportional to the drop in pressure which it undergoes. In the so-called impulse turbines this expansion

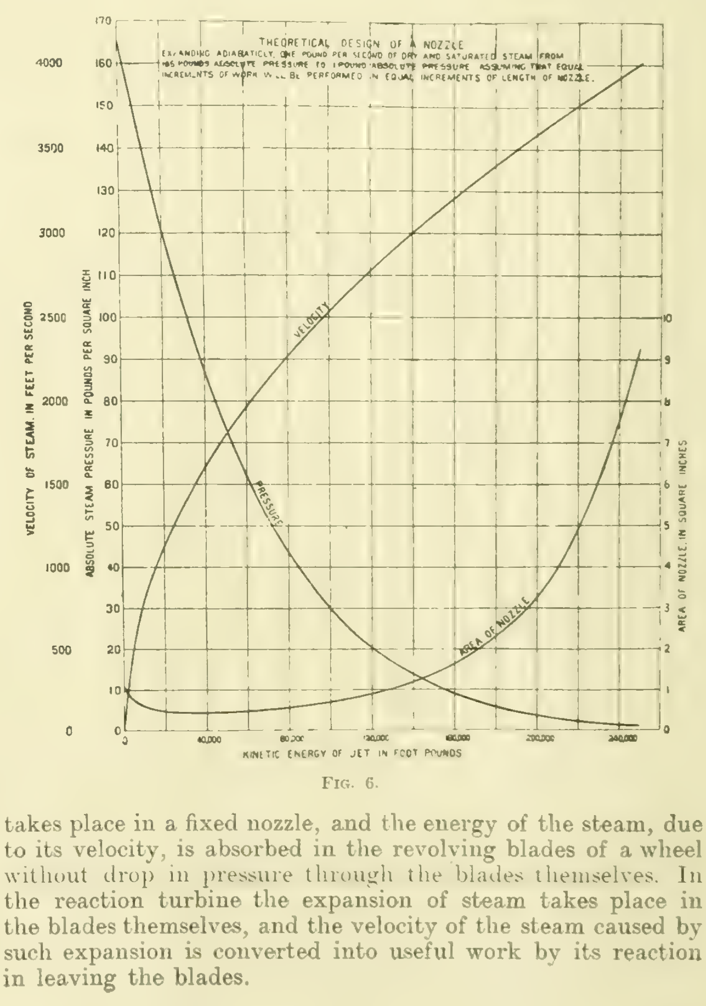


Fig. 6.

takes place in a fixed nozzle, and the energy of the steam, due to its velocity, is absorbed in the revolving blades of a wheel without drop in pressure through the blades themselves. In the reaction turbine the expansion of steam takes place in the blades themselves, and the velocity of the steam caused by such expansion is converted into useful work by its reaction in leaving the blades.

* From a paper on "Recent Developments in Steam Turbines," presented before the Franklin Institute.

As a matter of fact, all steam turbines make use of both the impulse and reaction of a steam jet acting on the blades. It is the way in which the blades are constructed and applied that distinguishes the different types of turbines, and it may be said that all impulse machines depend on the absorption of the steam velocity, due to a drop in pressure, through suitable nozzles, there being little or no pressure drop through the blades themselves; while the reaction turbine, on the other hand, utilises the velocity of steam, caused by a drop in pressure, through the blades themselves to rotate the turbine spindle.

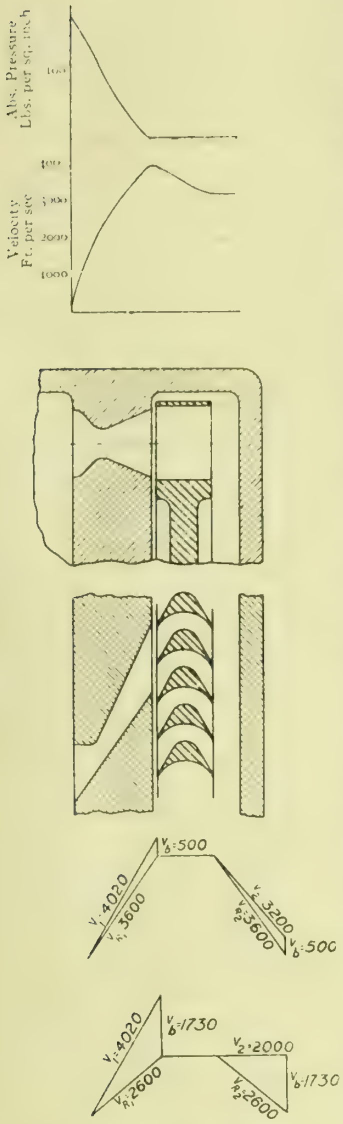


Fig. 7. De Laval Turbine.

Compounding stages of the simple impulse or reaction element constituted the development of the turbine to 1903. Prior to this date there were four distinctive systems in use: (1) The impulse, action, or velocity system represented by the De Laval turbine and its various modifications; (2) the multi-stage impulse represented by the Rateau and Zoelly turbines; (3) the subdivided multi-stage impulse system represented by the Curtis and Riedler-Stumpf turbines; and (4) the reaction or pressure system represented by the various forms of Parsons turbine.

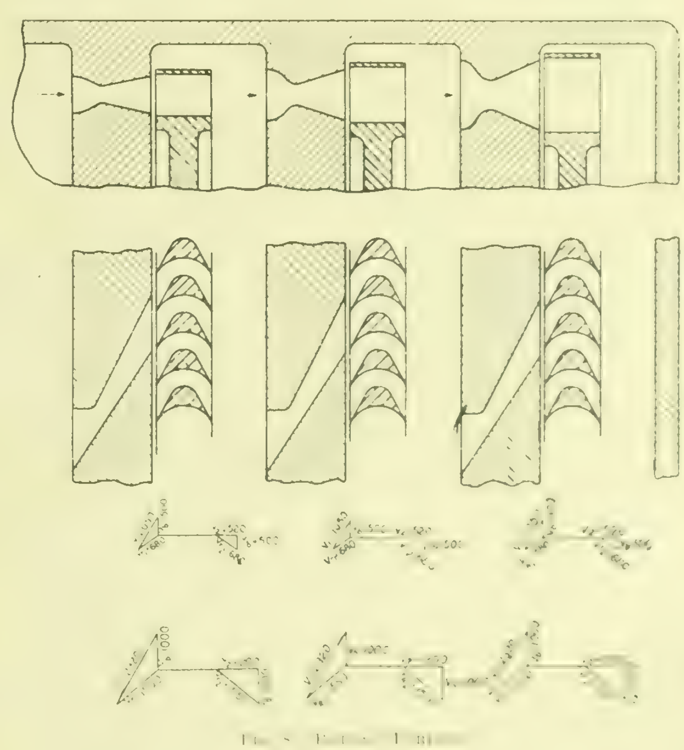
The distinctive characteristics of the impulse and reaction turbine elements lie almost entirely in the fact that in the impulse element expansion of steam is carried out within a system of nozzles, while in the reaction element expansion occurs within the blades themselves, both stationary and moving, but in successive small steps. The function of a steam nozzle is the production of the desired velocity, while that of its corresponding blade or blades is to absorb this velocity for the production of useful work. Here the pressure drop is almost entirely confined within the nozzle and is nonappreciable through the blades. On the other hand, in the reaction turbine there are no nozzles, the blades corresponding thereto, as noted above. In the expansion within the blades a reactive thrust is produced in the opposite direction from the issuing steam jet, which thrust forms the major part of the turning moment of the reaction turbine, and hence its classification as such. The remainder, which is but a small factor, is produced by impulse action of steam from the various stationary rows of blades. A definite relation must exist between steam velocity and blade velocity for the production of maximum efficiency. Theoretically, in the pure impulse system the moving blades must recede at one half the velocity of the impinging jet for maximum efficiency. In the pure reaction turbine the moving blades must recede at the same velocity as that of the steam jet in order to absorb all the velocity therein. This would appear to constitute a point in favour of the impulse system. In the reaction system the apparent objection is overcome by the simple expedient of employing more expansion stages. All this presupposes a tangential direction of the steam jet parallel to the plane of rotation. With side jets, such as are of necessity used in practice, it is impossible to obtain a complete reversal of the jet, and hence a part of the jet velocity is unavailable.

It is a general impression that the 1 to 1 velocity ratio must hold in reaction turbines. This is not the case, for the reaction system not only contains impulse principles but also uses side jets, so that the relative blade and jet speed, for the best efficiency, must fall somewhere between [illegible] and 1·0.

The multi-stage (Rateau) impulse system was developed to overcome the chief difficulty of the simple impulse element, viz., the efficient utilisation of the enormous steam speed resulting from a single expansion over wide ranges of pressure.

Fig. 6 plots the velocity resulting from the expansion of steam from a pressure of 165 lb. to 1 lb. absolute in a nozzle designed for uniform work. Thus a steam speed of over 1,000ft. per second is obtained for the full expansion to [illegible] vacuum. This would theoretically require a speed of 7,640 revs. per minute for an impulse wheel [illegible] diam., — a mechanical impracticability, but by subdividing the expansion into a number of stages the velocities per stage can be reduced to practical limits. This involves the familiar multicellular construction used in the Rateau turbine.

In the subdivided multi-stage (Curtis) impulse system a modification of the foregoing may be secured, viz., blade speeds two or three times lower than the jet speed may be used. This is accomplished by two or more impulse wheels per stage, each absorbing its share of the total velocity delivered by the nozzles. With a given jet velocity a 2-stage



[illegible]

impulse wheel would rotate at one-half the speed of a single impulse wheel, a three-stage wheel at one-third, &c.

The energy of a jet of steam of velocity V is $\frac{V^2}{2g}$, and the velocity of the steam with a suitably designed nozzle is dependent on the drop in pressure through such nozzle. It is customary to diagram by vectors the action of a steam jet through the various stages of a turbine, making certain allowances, established by practical experimentation, for losses due

to the physical properties of steam and the construction of the turbine elements.

In Figs. 7 to 13 inclusive such velocity diagrams are illustrated for the four types of turbines, viz., De Laval, Rateau, Curtis, and Parsons, together with diagrams of the blading of each type. The curves in the diagrams illustrate the action of the steam as regards pressure and velocity through the different stages. Such velocity diagrams comprehend the absolute and relative velocities of the steam jets and blades, the absolute velocities being recorded with reference to the earth, and the relative velocities with reference to the blades and steam jets. In the diagrams Figs. 7 to 13 the turbine rotors of the different types are taken with blade speeds of 500ft. per second and an expansion of the steam from 165lbs. absolute to 1lb. absolute.

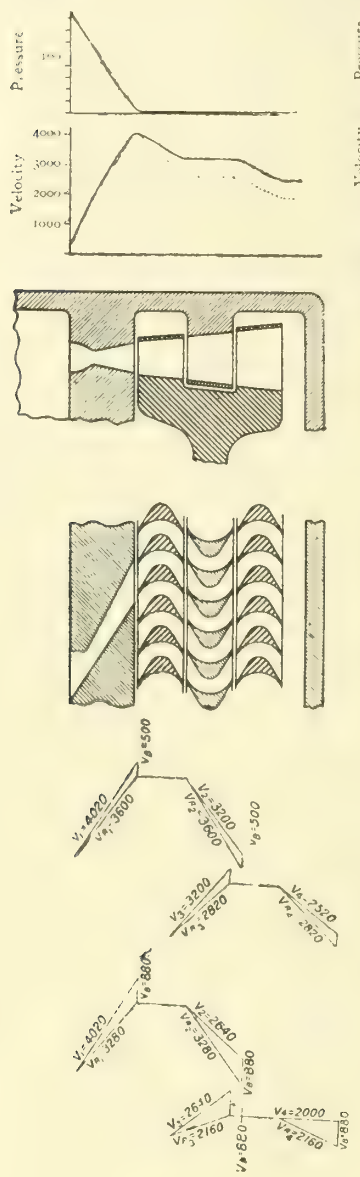


Fig. 9.

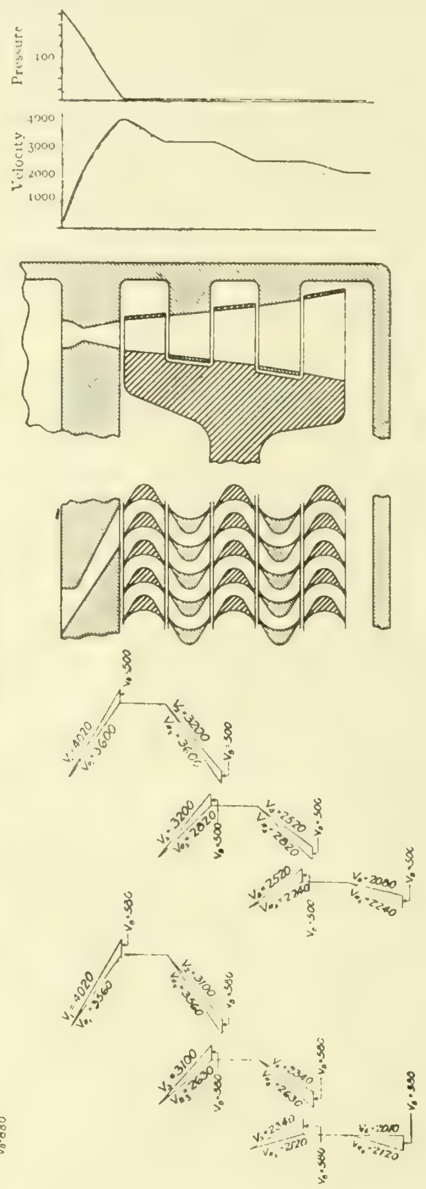


Fig. 10

Curtis Turbine.

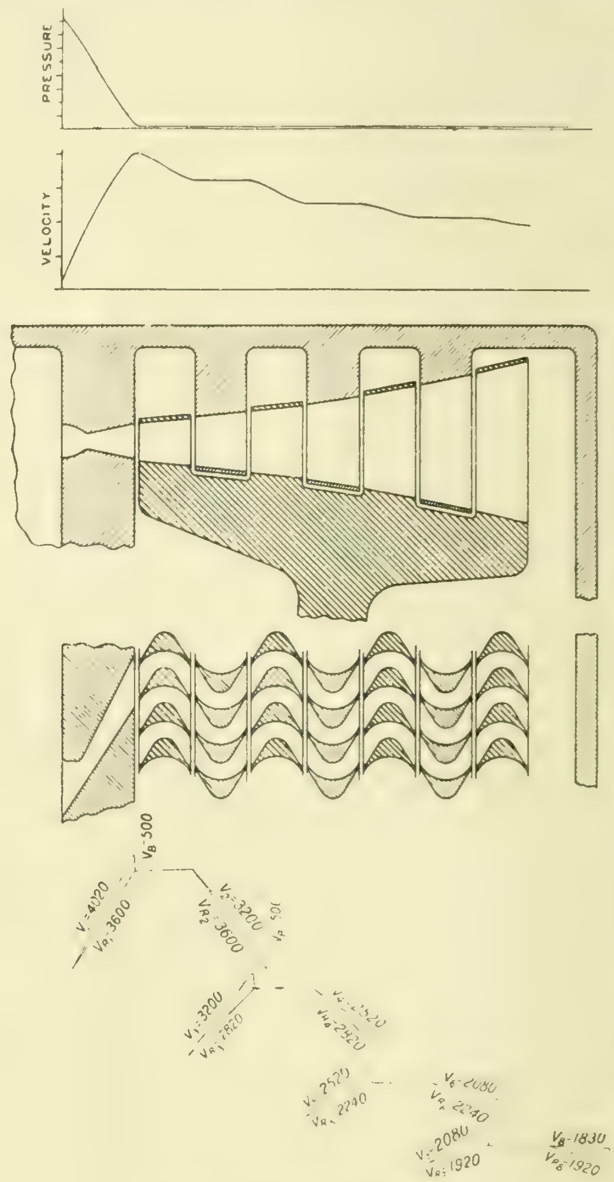


Fig. 11 Curtis Turbine

In the diagram of the De Laval turbine (Fig. 7) it will be seen that the jet of steam has a residual or leaving velocity after passing the wheel of 3,200ft. per second, which results in a failure to abstract the full energy of the jet proportional to the square of such residual velocity. In order that one row of impulse blades such as obtain in this example might extract the maximum energy from the expansion of the steam from 165lbs. to 1lb. absolute, it would be necessary to have a blade speed of 1,730ft. per second.

In the Rateau machine (Fig. 8) the residual velocity is 2,880ft. per second, representing an amount of energy unabstracted by the turbine proportional to the square of this residual velocity. If additional stages were added, this residual velocity could be abstracted without change in the blade speed, or the number of stages could be kept the same by increasing the blade speed to 1,000ft. per second.

In the Curtis turbine, by subdividing the impulse elements into two, three, or four rows of moving blades per stage the same jet velocity may be used with a blade speed of 500ft. per second, with leaving losses as shown in the diagrams Figs. 9 to 11 inclusive. It will be noted, however, that in the 4-division stage extreme velocities are encountered, as in the De Laval wheel.

These high steam velocities are, as in the Rateau turbine, materially reduced by diminishing the stage division and increasing the number of stages (Fig. 12). This system presents probably the best development of the subdivided multiple-stage impulse turbine; but for a complete machine there are difficulties to contend with in the maintenance of proper steam distribution through the later stages. Considering, however, the first stage, of two subdivisions by itself, the advantage of this type of element is apparent. Comparing, for instance, the first stage expansion with that of a similar expansion arrangement in a Rateau turbine, it can be shown that four individual Rateau stages are required to do the same work as this single subdivided two-row stage (assuming, of course, the same blade speed, viz., 500ft. a second, and the same pressure drop, 165lbs. to 50lbs. absolute).

In the Parsons turbine the process of subdividing the steam expansion (as illustrated in Fig. 13) resolves itself into a relatively large number of rows of blades. An important result secured by this subdivision is the uniformly low steam velocities through the turbine. When velocities of 1,000ft. to 2,000ft. per second are encountered throughout the Rateau and Curtis turbines the corresponding velocities in the Parsons machine will vary from 150ft. to 1,000ft. per second. As friction losses are a function of velocity, this relatively

low velocity is an important point, and probably to a large degree accounts for the high efficiency of this system.

It is evident from the foregoing that the application of a turbine design to commercial use must embody a knowledge of

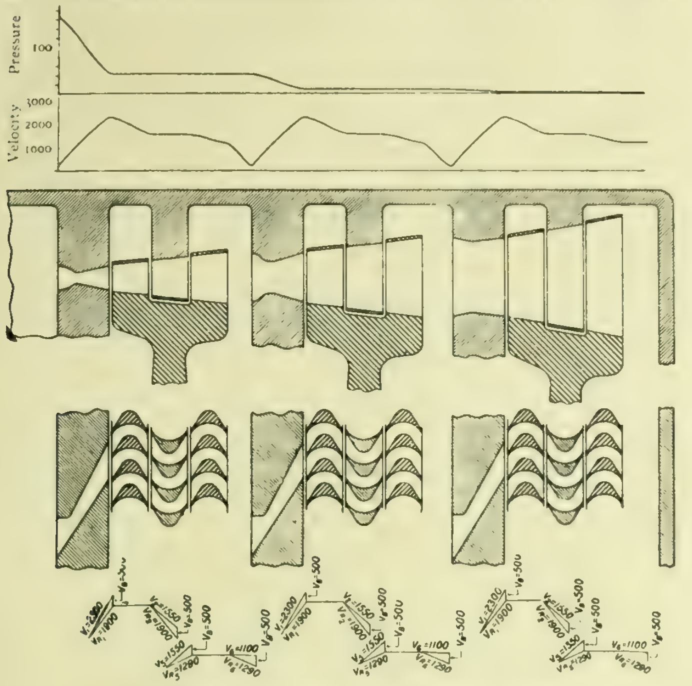


FIG. 12.—SUBDIVIDED MULTI-STAGE IMPULSE TURBINE.

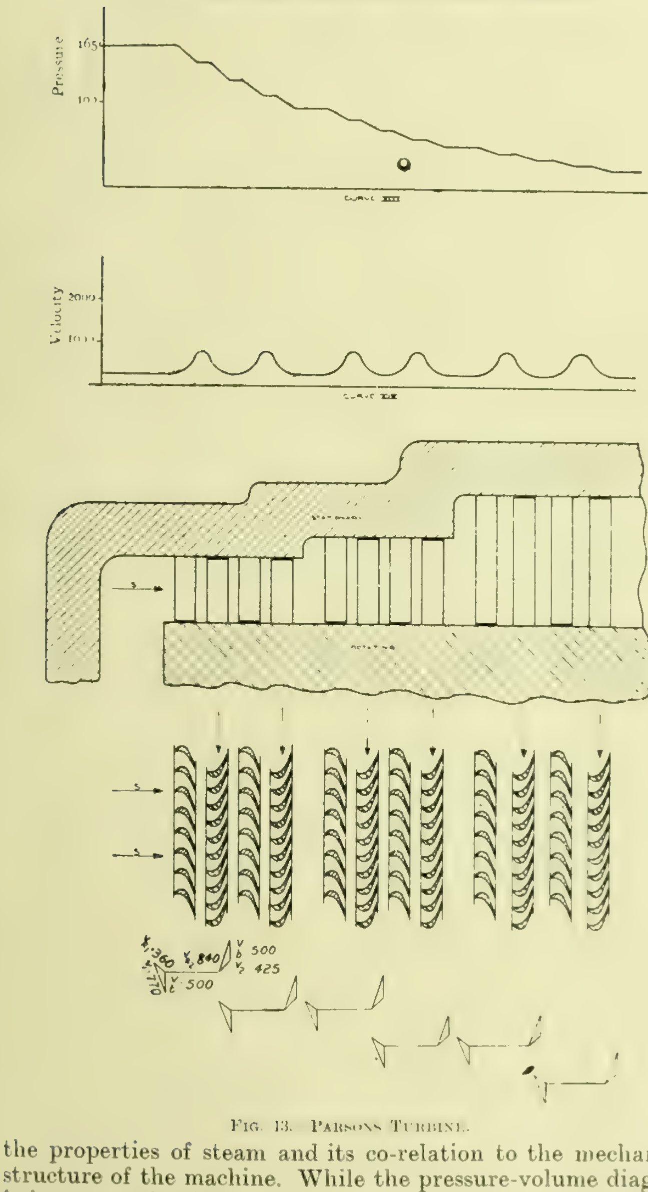
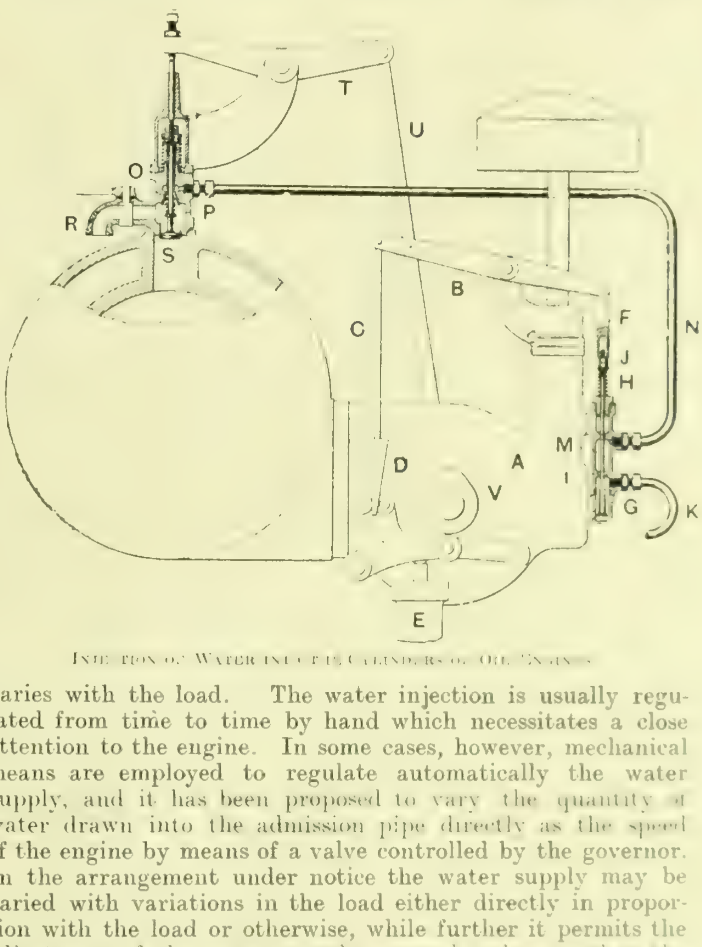


FIG. 13. PARSONS TURBINE.

the properties of steam and its co-relation to the mechanical structure of the machine. While the pressure-volume diagram is important in the design of piston engines, it has little use, except by comparison, in the determination of the action of steam in the turbine. The entropy temperature diagram and the conversion of pressure to velocity under adiabatic expansion, together with the co-relation of heat drops, form the basis of turbine calculations. The development of the turbine has therefore led to a closer study of the properties of steam, and by experimental work and mathematical deduction the physical properties of both saturated, wet and superheated steam have now been determined with certainty and precision, so that computations based on these show satisfactory concordance.

INJECTION OF WATER INTO THE CYLINDERS OF OIL ENGINES.

THE accompanying illustration shows an arrangement designed and patented by Messrs. Tangyes, Ltd., Cornwall Works, Smethwick, Birmingham, in conjunction with Mr. James Robson, to effect automatically a more efficient regulation of the water injection into the combustion chamber on the suction stroke of the piston of an oil engine than is obtainable by the usual automatic regulating mechanism. The quantity of water injected into the cylinder should vary with variations of the load on the engine, that is to say, when the engine is running without or practically without load, very little, if any, water is required, and when the engine is running at full load the maximum amount of water is required and the amount necessary at intermediate loads



INJECTION OF WATER INTO THE CYLINDERS OF OIL ENGINES.

varies with the load. The water injection is usually regulated from time to time by hand which necessitates a close attention to the engine. In some cases, however, mechanical means are employed to regulate automatically the water supply, and it has been proposed to vary the quantity of water drawn into the admission pipe directly as the speed of the engine by means of a valve controlled by the governor. In the arrangement under notice the water supply may be varied with variations in the load either directly in proportion with the load or otherwise, while further it permits the adjustment of the water supply control valve so that the same maximum quantity of water can be ensured should the engine be arranged to run at a higher or lower speed for the maximum or any given load.

Referring to the illustration, which represents partly in end elevation and partly in vertical section a portion of an internal-combustion engine in which liquid fuel is employed. A is the governor body having pivoted on it the lever B. To one end of this lever is connected a rod C terminating in the wedge D which, according to the position of the governor and load on the engine, allows of a longer or shorter stroke to be given to the oil or liquid fuel pump E. The other end of the lever B operates through a depending rod F, the stem of the water regulating valve G and on the downward motion of the rod F the valve G is opened, the closing or partial closing of the valve being effected by the coiled spring H acting against the regulating screw nuts J when the rod F

is raised. By the regulating screw nuts J the valve rod G may be set to give the same water supply at maximum load and the same variations due to varying load at whatever speed it may be determined to run the engine. When the valve G is open the water which is admitted by the pipe K passes through the cylindrical opening L in the valve box M from which it flows through the pipe N to the water inlet valve O in the combined air and water valve box P. The admission of air into the valve box P is regulated by the plug cock R and the air and water valves S and O are operated at the proper times by means of the lever T and rod U from the side shaft V of the engine in the usual manner. The air and water valves S and O can be automatically operated by the suction produced by the piston of the engine cylinder when making its charging stroke. The water inlet valve G is of a slightly plain tapering form, but instead of a single tapering part, two or more tapering parts preferably of different angles may be made on the valve G if thought necessary or desirable to ensure the passing of the correct quantity of water for the particular load on the engine. The lower portion of the valve G is preferably cylindrical and of a diameter proper to fit or approximately fit the valve opening L, controlled by the valve G. By this construction the water supply can be entirely cut off or practically so for any required distance before the governor reaches its highest position which corresponds with the lighter or lightest load on the engine which is an important requirement on such loads. The valve G is provided in addition with a valve head capable of seating itself tightly on a corresponding seat in the opening L of the body of the valve box M, so that when the engine is running with very light loads the water is prevented from leaking past the valve G.

From the foregoing description it will be understood that the amount of water admitted to the combustion chamber of the engine is correctly proportioned and properly regulated by the lifting or lowering of the valve G through the action of the governor, and hence varies with the variations in the load on the engine which renders unnecessary the close attention on the engine which ordinary hand regulation requires and ensures the regulation of the water admission to the combustion chamber with greater nicety or accuracy than can be effected by hand or by the automatic controlling mechanism heretofore proposed.

METAL QUOTATIONS.

TUESDAY, MARCH 4TH.

Aluminium ingot	95/	per cwt.
„ wire, according to sizes, &c. ......from	112/–	„
„ sheets „ „ ...... „	120/–	„
Antimony ....£34/–/– to	£36/–/–	per ton.
Brass, rolled	8¼d.	per lb.
„ tubes (brazed)	10⅜d.	„
„ „ (solid drawn)	9d.	„
„ „ wire	8⅜d.	„
Copper, Standard	£66/5/–	per ton.
Iron, Cleveland	64/1½	„
„ Scotch	70/1½	„
Lead, English	£16/15/–	„
„ Foreign (soft)	£16/2/6	„
Mica (in original cases), small	6d. to 3/–	per lb.
„ „ „ medium	3/6 to 6/–	„
„ „ „ large	7/6 to 11/–	„
Quicksilver	£7/15/–	per bottle.
Silver	$27\frac{7}{16}$d.	per oz.
Spelter	£24/15/–	per ton.
Tin, block	£217/–/–	„
Tin plates	14/–	„
Zinc sheets (Silesian)	£28/17/6	„
„ (Stettin; Vieille Montagne)	£28/17/6	„

The Institution of Mechanical Engineers.—An ordinary general meeting will be held in the Meeting Hall of the Institution on Friday evening, March 14th, at 8 o'clock, when a paper on "Some Effects of Superheating and Feed water Heating on Locomotive Working," by F. H. Trevithick and P. J. Cowan, will be read and discussed. A meeting of the graduates will be held on Monday, March 10th, at 8 p.m.

THE DIESEL ENGINE AS MOTIVE POWER IN THE MERCHANT MARINE.*

WITH SPECIAL REFERENCE TO THE FIRST SUCCESSFUL MOTOR SHIP, "CHRISTIAN X."

BY OLE L. OLSEN.

THE subject of the Diesel engine and its relation to the merchant marine means nothing less than a revolution in ship propulsion. It may be in order to give a very short résumé of the development of the internal-combustion engine, as history shows that the idea of employing the expansion force of air and fuel directly in the working cylinders dates back to the days before the advent of the steam engine.

In 1670 to 1680 it was proposed by Huyghens and Papin to use gunpowder as fuel—which is the earliest suggestion we know of. In 1791 English patents were issued for a kind of turbine in which gases which were generated from fuels were to be used with air and water, and were to exert their forces in the turbine after having been ignited, and in 1794 we find another English patent covering an oil engine where the fuel was to be evaporated in the cylinder itself and ignited by flame after half of the stroke had been completed. In 1801 M. Lebon took out a French patent for a double-acting engine using two pumps for mixing and compressing air and illuminating gas in a reservoir, and from there forcing it to the double-acting working cylinder where it was electrically ignited. Several other patents were issued, especially in England, during the following years, covering various internal-combustion and explosion principles.

About this time a young German merchant built an experimental engine, the principle of which was based on admission of the mixture of gas and air, compression, ignition, and exhausting of the spent gases, all in one cylinder. It was anything but a success, and, discouraged over the apparent failure, he constructed the Otto atmospheric engine, a vertical machine, where gas was admitted under the piston, the piston was driven upwards by the combustion of the charge, and transmitted power to the shaft and flywheel on the downward stroke only when actuated by atmospheric pressure. Some 5,000 of these engines were built, and some are still in operation. A French engineer, Beau de Rochas, proposed the idea—but never put it to a practical test—of using four strokes to a cycle and compressing the charge before ignition in the working cylinder; and in applying this principle to his first experimental engine, Otto developed the first practical 4-cycle engine, generally known as the Otto engine. Some inventors went a step further and constructed a 6-cycle engine, expecting to get higher economy by using a third stroke to admit pure air and expel it again after the spent gases had been exhausted, but their hopes were not realised.

About 1893 Prof. Rudolph Diesel, of Germany, designed what is now known all over the world as the Diesel oil engine. His engine is not an explosion engine, but a combustion engine, and the principle is, in short, as follows: Pure air is drawn into the cylinder and compressed to a point at which the temperature of the air is equal to or higher than the combustion temperature of the fuel used, generally from 350lbs. to 550lbs. per square inch. Just as the piston starts on its outward stroke, the fuel is forced in under a slightly higher pressure than that in the cylinder, and in the form of a fine spray. The high temperature of the compressed air forces the fuel to ignite instantaneously and burn as it enters the cylinder. The temperature of the gases is thus kept constant during the combustion, and no explosion takes place. The first practical engines, however, did not appear until M. Lenoir, in 1860, built a 1 h.p. double-acting gas engine with 3in. diam., 5½in. stroke.

We shall now go over to the latest success of the Diesel engine in its application to the merchant marine. A great many experiments have been made to successfully use the internal-combustion engine for marine use, and it is, of course, well known that this motive power has been exceedingly successful for smaller craft, but notwithstanding the fact that the leading countries of the world have invested fortunes in experiments, they did not succeed in bringing out

* Paper read before the Louisiana Engineering Society, October 14th, 1912, and reproduced from the Journal of the Association of Engineering Societies.

a type of engine suitable for the great freight carriers, and it was not until January, 1912, that the first large motor ship made its appearance. This boat, "Selandia," was built by the Danish ship and machine builders, Burmeister & Wain, in Copenhagen, Denmark, and we have recently had her sister ship "Christian X." in the port of New Orleans after her first trip across the ocean.

Burmeister & Wain have built several ships for the Danish East Indian Steamship Company, and as the firm had been very successful in building stationary Diesel engine plants of large dimensions, the steamship company and the builders decided to make the experiment which turned out to be a success, so much so, that six months later, the Burmeister and Wain Company had orders on their books for 12 more boats for various nations.

The ship "Christian X." is 370ft. long, 53ft. beam, and 30ft. deep. She carries 7,000 tons and will make 12 knots (13·8 statute miles) with full load, and her two main engines of the Diesel type develop each 1,250 i.h.p. She has two secondary engines not used for propelling, developing each 250 i.h.p. At the trial run she developed 1,700 i.h.p. in each of the main engines and obtained a speed of 12¾ knots. The machinery, except the winches on deck and the steering gear, is all in one room, in order to make everything as accessible and economical as possible as regards the attendance. Under normal conditions one engineer and two assistants are needed, and while the assistants are looking after all secondary machinery, the engineer has from his operating room full view to the main engines, switchboard, fuel oil pumps, oil tanks, &c. The full engine crew consists of three engineers, six assistants, one electrician, and two boys for cleaning up, &c., and the same size steamship would need five engineers, two or three oilers, one electrician, and 10 to 12 firemen.

The machinery consists of two main engines, two secondary engines, two motor transformers, two cooling water pumps, two lubricating oil pumps, one fuel oil pump, ballast pump, ice machine, various air compressors, two generators, one small donkey boiler, one fresh-water pump and one evaporator. The main engines are 4-cycle motors directly connected to propeller shaft. Each engine has eight cylinders of 20⅞in. diam. and 20¾in. stroke and makes 140 revs. per minute, corresponding to 12 knots per hour. There are two of these. The secondary engines are ordinary stationary 4-cycle Diesel engines. There are two of these, and each has four cylinders of 12⅞in. diam. and 17¼in. stroke. The number of revolutions is 230, and indicates at normal load 250 h.p.

The air compressors for the main engines are single acting pumps taking the air at 300lbs. pressure from the receiving tanks or supply tanks, and compressing it to approximately 900lbs. in one cycle. From these compressors the air is carried to separating tanks where oil and water are separated from the air, and from these tanks it goes to the fuel valves of the engines to be used in injecting and atomising the fuel oil. A disc valve is used instead of the ordinary needle valve, and it opens into the cylinder, which gives better atomising and, therefore, more complete combustion. The compressors are driven by an overhanging crank placed on the front end of the crank shank, and are constructed so that they can work with either half or full stroke. Under normal conditions half stroke is ample to furnish the engines with sufficient air for injecting and atomising, but in case one compressor should get out of order, the other can feed both engines for full speed.

(To be continued.)

National Physical Laboratory.—The Government has, we learn, decided upon a very large extension of the work of the National Physical Laboratory at Teddington. A sum of £35,000 is being spent on new buildings and equipment, the Treasury having made a grant of £15,000 towards this amount. The laboratory is to be entirely reorganised, and under the new scheme the work will be classified as follows: General electrical measurements, engineering research and tests, aeronautical investigation, road making experiments, metallurgy building, electrical research, standardisation of the sources of light, metrology building, standardisation of weights, &c., and the William Froude national tank for experiments on models of ships.

INDUSTRIAL AND TRADE NOTES.

Shipbuilding Orders for the Clyde.—Messrs. Barclay, Curle & Co., Ltd., Whiteinch, have, we learn, booked orders for six steamers each of about 150ft. in length for the British India Steam Navigation Company. This firm have now on hand for the same line no fewer than 11 vessels.

Brown Boveri Turbine.—We have received from Richardsons, Westgarth, & Co., Ltd., Hartlepool, an illustrated pamphlet describing the combined impulse and reaction turbine they are now building, and of which they have already supplied a number of machines. The turbine is of the same type as that built by Messrs. Brown, Boveri, & Co., of Baden, Switzerland.

A Reliable High-lift Tandem Pump.—We understand that Messrs. Mather & Platt, Ltd., have received an order from Messrs. Baldwins, Ltd., Bryn Colliery, S. Wales, for a duplicate pump to the tandem pump which they supplied five or six years ago, and which was at that time the first pump they had ever made of over 1,000ft. head. This pump has never had a penny piece spent upon it since it was put to work, and has had to run daily.

Proposed New Light Railway in Yorkshire.—A scheme is under consideration by the Yorkshire Wold landowners for the construction of a light railway from Wharram-le-Street, on the Driffield line, to Hunmanby, on the Hull and Scarborough line. The line would be about 19 miles in length, and would proceed more or less at a level through the heart of the wold country, which at present is very deficient in railway facilities.

The French Motor-Car Industry.—Statistics relating to the motor car industry in France show an immense growth. In 1902 France exported motor vehicles to the value of £1,200,000. In 1912 the total reached £6,408,000. It is estimated that motor works give employment to over 65,000 persons, with a yearly wages bill of over £6,000,000. Foreign cars in France do not seem to be much in request, as purchases amounted only to £464,000 last year, but of these British cars seem to have claimed a very fair proportion.

Welsh Tinplate Trade.—A meeting of South Wales tinplate manufacturers was held at Swansea on the 25th ult. to consider a restriction of output consequent upon over-production. Over 500 mills were represented, of whom 393 voted for a stoppage, and 100 against, while 35 were neutral. This being considered an insufficient majority for restriction to effect any satisfactory easing of the situation, matters remain as before, and there will be no systematic stoppage. Many works, however, will have a restricted output in some way or another.

Clyde Shipbuilding Output.—The Clyde shipbuilding yards produced a satisfactory amount of tonnage during the month of February, viz., 47,050 tons, but as the output for January was unusually small the total for the two months is somewhat lower than the average of recent years. The two months' total this year is slightly under 57,000 tons, while that of last year was 83,000, and that of 1911 66,000. While the yards are all fully employed very few orders were placed during February, and builders report that the number of enquiries for new vessels has decreased greatly.

The World's Greatest Waterfall.—Dr. Percy Rendall recently described the visit he made to the Kaieteur Fall, British Guiana, in July last. Kaieteur, which Dr. Rendall asserts is the world's greatest waterfall, was discovered by Mr. Barrington Brown when he was descending the Potaro River in 1871. It was thoroughly explored and measurements taken two years later. The fall has a height of 822ft., which is rather more than twice that of the Victoria Falls and five times that of Niagara, and its available average energy is computed at over 1,250,000 h.p., or nearly 65,000 h.p. more than that of Niagara.

Italian Shipbuilding Industry.—According to the "Borsen Zeitung" (Berlin), the Italian shipbuilding yards participated in the general prosperity which characterised shipbuilding during 1912. At the end of last year there were at least half a dozen large vessels being built for the Italian mercantile marine, whilst at the end of 1911 scarcely any of the larger types of vessel were being built in Italy. Nevertheless, no orders of any importance have been coming in lately, and it is to be observed that a number of the larger Italian shipbuilding firms have not a single vessel under construction in Italy. In 1912 only six vessels of more than 1,000 tons capacity (gross) were built in Italian yards, including only one of 5,000 gross register tons.

A Geared Turbine Steamer.—Messrs. A. & J. Inglis, Glasgow, launched on the 26th ult. the turbine steamer "Elgin," the last of three sister ships which they have built for the South Indian Railway Company. They have a length overall of about 200ft., a breadth of 38ft., and a depth to the promenade deck of nearly 19ft. Their gross tonnage will be rather less than 700. The propelling machinery, which has been constructed by the builders

of the ship, consists of two sets of geared turbines of the latest Parsons type, one high pressure and one low pressure being coupled to each of the two shafts by means of machine cut gears, each shaft driving one of the twin screws. The revolutions of the turbines will be about 3,500 per minute, while those of the propellers will be 500.

Dearth of Puddlers in the Midlands. At the annual meeting of the Midland Iron and Steel Wages Board, held at Birmingham on Monday last, Mr. George Macpherson, chairman, said the Board had granted a bonus of 6d. per ton to puddlers, with a view to improve their condition and to tempt more young men to enter that branch. The prospects of the iron trade were better than for many years past. Last year the output of the 17 selected firms of which the sliding scale was based increased by 5,000 tons, and but for the coal strike the increase would have been 20,000 tons. Engineers were reverting to the use of iron. Mr. Wm. Ancott, the operatives' secretary, said that young men would not learn puddling until the arduousness and fatigue of the occupation were diminished, as at present it broke the strongest man.

Petroleum Production in the United States.—The preliminary estimates place the production of petroleum in the United States in 1912 at 220,200,000 barrels (of 42 United States gallons), valued at $150,000,000, as compared with 220,449,301 barrels, valued at $134,044,752 in 1911. These figures show a very slight falling off in production, but the largely increased demand has enabled the producers to get considerably enhanced prices for oil, viz., 68 cents per barrel on the average, as compared with 61 cents in 1911. The year 1912 is remarkable as being the first year since the inception of the industry in 1859 in which the amount produced has not shown an increase over any previous year. On account of the very great increase in consumption the amount of high grade oil in stock at the end of the year was only about 69,000,000 barrels, as compared with 81,789,400 barrels at the beginning of the year, a reduction of about 15 per cent.

Large High-Speed Reduction Gear.—The Westinghouse Machine Company and the Westinghouse Electric and Manufacturing Company have recently constructed for the Cleveland Electric Illuminating Company, Cleveland, Ohio, a direct current turbo generator, rated at 3,750 kw. The turbine has a speed of 1,800 revs. per minute. By interposing a Westinghouse reduction gear with an hydraulically supported floating pinion frame having a ratio of 10 to 1 between the two members of the set, the generator is driven at a speed of 180 revs. per minute. The efficiency of the generator has been found to be 94 per cent., so that the gear transmits about 5,350 b.h.p., but on several occasions the load on the plant has exceeded 6,000 h.p. While the capacity of this gear is not as great as that of the experimental set tested at the Westinghouse Machine Company's works in 1909, the reduction ratio is twice as great, and the speed of the turbine is 20 per cent. higher.

Shortage of Fuel in Russia. The growing consumption of fuel in the various industries in Russia is becoming a matter for serious consideration, reports the American Consul at Odessa. It appears that for the time being the oilfields cannot give any increased amounts of petroleum, but, on the contrary, they are likely to furnish less fuel unless rich flows can be struck in places as yet untouched. The forests have been called upon for fuel quite out of proportion to the possibility of reproduction. Wood is therefore rapidly becoming dearer and, in this district, those engaged in the business foretell a further increase in price in a year or two, amounting possibly to 50 per cent. Of peat there is a great abundance in many places, but so far this kind of fuel, valuable as it is, has not met with much favour outside of certain industries and certain localities where wood has given out. Therefore, the whole burden is falling on coal, of which a great deal more will have to be mined.

Ghent International Exhibition.—The fact that no less than 130 Congresses are to be held during the six months that it is open shows how widespread is the interest which is being taken in the Ghent International Exhibition. Of these, about one-half are international. As most of these 130 Congresses will last several days, there will be occasions when as many as five will be sitting at the same time. But there will be plenty of accommodation, for an indefinite number might find room in the great permanent building, the Palais de Fêtes et d'Horticulture, which is one of the most striking sights of the whole Exhibition. The size of this great building is difficult of description, but it can be understood to some extent from the fact that the span of its main hall is far greater than that of the Crystal Palace, that this hall contains 3½ acres, and the second or small hall, 2 acres. The rooms which will be devoted to Congresses and committees are on a similarly large scale, both as to number and size.

American Pig-Iron Production in 1912.—According to a bulletin, dated January 30th, issued by the American Iron and Steel Institute, the production of pig iron in the United States in 1912 was as follows, the figures for the two previous years being added for purposes of comparison:—

	1910.	1911.	1912.
	Tons.	Tons.	Tons.
Bessemer and low phosphorus	11,245,642	9,409,303	11,667,656
Basic	9,084,608	8,520,020	11,394,477
Charcoal	396,507	278,676	347,025
Ferro-manganese	71,376	74,482	125,379
Spiegeleisen	153,055	110,236	96,346
Foundry, ferro-silicon, &c.	6,352,379	5,256,830	6,096,254
Total	27,303,567	23,649,547	29,727,137

Rail Motors on Australian Lines.—Considerable attention is being devoted in Australia to the practical advantages of both steam and internal-combustion rail motors for use on branch lines, or where traffic is light. The South Australian Railway Commissioners recently ordered an internal combustion rail motor from a local firm. The same Commissioners made another new departure by ordering from the United Kingdom an internal combustion locomotive for use on light lines. Two petrol rail motors of foreign manufacture, which have been in regular service on the Victorian State Railways since May last, are stated to have given satisfaction. Arrangements have also been made for the trial of a steam rail motor of the type used on the Great Western Railway (England). The Commisioner of the Tasmanian State Railways is of the opinion that a considerable economy could be effected by the use of rail motors for passenger traffic on some of the branch lines, and states that the Agent General in London for Tasmania is making enquiries with a view to finding a suitable type of motor, and that a special report will be furnished to the Tasmanian Government in due course.

The Training of Apprentices. In the course of a paper on the education and practical training of engineers and artisans engaged in the engineering trades, read before the Birmingham Association of Mechanical Engineers, on Saturday last, Mr. T. Reid said that a system should be established whereby employers should work two squads of apprentices, one squad being at work while the other squad was going on with higher training in the trade schools, or a combination of secondary and trade schools training, arranged to meet their educational needs, having regard to their future. There was a strong opposition on the parts of youths and their parents to anything in the nature of an agreement binding the youths to serve an apprenticeship which would, in the end, make them all round, good workmen. The fundamental mistake of the present day was that the apprentices were valued by many employers as a kind of cheap labour, out of whom the greatest return must be got regardless of their future and the future of the engineering trade of the country. During the past twelve years he had noticed unmistakable evidences of a growing lack of skill on the part of the youths who attended the engineering workshops of the technical schools. Much that they had learned or picked up in the shops had to be unlearned, and this constituted the greatest difficulty the instructors had to contend with.

The Rotoplunge Pump.—This pump, which has recently been placed on the market, consists of a cylindrical casing, having inlet and outlet passages, and containing a rotor in which are a series of radial cylinders. The cylinders have single-acting pistons pivoted to a crosshead, which runs on roller bearings inside the end cheeks of the casing. The roller bearings are set eccentrically in relation to the rotor shaft, with the result that as the rotor revolves the pistons make a reciprocating movement. The casing is divided into two parts—a suction side and a delivery side—by shoes which bear on the outside of the rotor. The piston travels are so arranged that they move inwards the first half revolution of the stroke, drawing the liquid in on the inlet side, and outwards the second half revolution, forcing it out on the outlet side. It is therefore a positive action valveless pump, and with a very high number of revolutions only a slow piston speed. The pump is claimed to be especially suitable for work in breweries, creameries, and chemical factories, also for pumping semi liquids like molasses, viscid tar, and sewage. It has been successfully applied to the hydraulic transmission of power, air compression, blastfurnaces, and condensers working with steam turbines. It requires no special foundation, occupies very little space, and is light.

Increased Cost of Petrol. During the past week two of the leading companies concerned in the supply of motor spirit has raised the price of best quality petrol to 1s. 9d. per gallon, and the second quality to 1s. 7d. per gallon. The highest price hitherto has been 1s. 7d. per gallon for best quality. This increase has, according to a correspondent of "The Times," been brought about by the practical cessation of the imports of American petrol into Great Britain. Since January 1st to the present time these had

amounted to only 188,000 gallons, against over 1,000,000 gallons for the same period of 1912. This was not surprising, seeing that on the basis of the existing values of petrol in New York the equivalent price for sale in London would be 1s. 10½d. per gallon, whereas until last week the price had been 1s. 7d. Nor was it only in the United States that prices were on a higher level than in the United Kingdom. In France, Germany, Italy, and Scandinavia prices were materially higher. The fact that the increase in consumption was world wide was too often lost sight of. The chief difficulty to-day, he added, was the provision of sufficient transport, not a scarcity in the supply of petrol. The idea that the rise in the price of petrol or the curtailment of the supplies was due to the existence of a trust was a fallacy. There was no combination to account for it. It was simply the inexorable law of supply and demand which regulated the price, and if new supplies on a large scale were discovered the price would go down.

Associated Manufacturers of Tramway and Railway Material.—Mr. J. Sutherland Warner, chairman of Council of the Associated Manufacturers of Tramway and Railway Material, in a recent communication refers to the objects of the association. He states that, having regard to the enormous annual purchases made by tramway and railway officials, and the well known difficulties experienced in framing specifications and suitable standard clauses governing conditions of tender, acceptance, and completion of contracts, those officials who act as purchasers have every right to expect of the manufacturers some more concrete and authoritative expression upon standard forms of clauses, acceptable alike to both buyer and seller. It is only by a recognised association that such work as the settlement of acceptable standard clauses and bases of intercourse can be effected and maintained, and occasional special references on extraordinary points receive consideration and decision by a representative council, whereby smooth working and the avoidance of lengthy and unprofitable disputes can be ensured. The subject of exhibitions, their support and encouragement, will also receive thorough consideration by the association from time to time. The council have already considered the question of national and international representation, and having been influenced by the fact that manufacturers other than British do actually take their part in the supplies of tramway and railway material purchased in Great Britain, they have decided to admit to the association, and thereby control, foreign manufacturers. Applications for membership should be sent to the hon. secretary, Mr. William Hopkins, Westminster Palace Hotel, S.W

Scientific Training of the Collier. A plea for the better technical education of the miner was made by Mr. George H. Winstanley, the President of the National Association of Colliery Managers, in a lecture delivered to the members of the Yorkshire branch, at Leeds, on Saturday last. There could be little doubt, he said, that the colliery manager of to-day was a man of broader outlook, wider knowledge, greater skill, and higher training than the colliery manager of former generations. Indeed, there would be something seriously wrong were this not so. While raising the standard of the manager, however, there was a risk of overlooking the question of the training and qualification of the workman, on whom, after all, the safety of the mine very often largely depended. If they considered for a moment the things which a miner ought to know for his own and the general safety of the mine, the kind of knowledge needed by the subordinate official in order that he might perform his duties with efficiency and skill, it would be obvious that something more was required than mere practical experience in the mine. Obviously, among other things, the miner should know something about the general principles of ventilation, about the atmosphere, and how and why the atmosphere of the mine might differ from the normal atmosphere. He should know something of the properties of the gases met with in mines, and should be able not only to recognise indications of danger and conditions which might lead to danger, but should also know exactly what he ought to do under various conditions, and why. Knowledge of these things could not be imparted by placing before him mere statements of fact and formulæ; he must rather be led to acquire his knowledge not so much by appealing to his imagination as to his powers of observation and reasoning. The method adopted should indeed tend to develop and stimulate those qualities. It must be distinctly practical, and the evidence put before him should be progressive and fairly obvious in character.

British Trade with Russia.—A report by H.M. Consul at Vladivostok (Mr. R. M. Hodgson) on the trade of that district in 1911 states that the trade with the United Kingdom in 1911 remained pretty much what it always has been, with perhaps a slight tendency towards improvement. Among orders placed in the United Kingdom recently may be mentioned brickmaking machinery, crucible steel, lathes and workshop equipment, motor boat engines, and refrigerating machinery. British portable engines continue to hold their own, and the importation of corrugated and flat iron sheets, always important, is increasing in volume. The exploitation of the natural resources of the country, now encouraged by a liberal and sympathetic attitude on the part of the Administration, is attracting the capital which is essential to it. The purchasing power of the community is therefore increasing; it remains to be seen whether British manufacturers will make some serious effort to establish themselves in a market which they have been content hitherto to leave untouched. It should be at once said that the dispatch of an occasional traveller will not effect this object, nor will the distribution of the most alluring catalogues be of much avail. British firms must be actively and efficiently represented on the spot, and till this is done no real improvement in the position can be hoped for. They must bear in mind that German trade has gained predominance at Vladivostok by starting from small beginnings when the Russian occupation was in its infancy, and that it has grown up with the country. The Consul mentions that careful packing is essential in the case of goods (machinery especially) intended for Vladivostok. Cargo for that port, unless sent viâ Shanghai by fast steamers, is generally three months or more on the way, and has, more particularly in the winter months at Vladivostok, to go through extremes of temperature. Bright parts of machinery must be protected and thoroughly coated with antirust composition. Another point worthy of attention while on the subject of machinery is the importance of sending in good time full specifications and working plans. When supplying boilers certificates of factory tests must always be sent, and it must be remembered that the requirements of Russian law must be studied and complied with.

Shipyard Agreement.—The terms of the proposed new national working agreement between the Shipbuilding Employers' Federation and the Boilermakers' Society was discussed at a conference held on the 27th ult. at Edinburgh between representatives of the two organisations. The men's delegates presented to the employers their proposals for an agreement. These were, generally, on the lines suggested in the last monthly report of the society, the principal stipulations being that: (1) There shall be a neutral chairman at all local conferences. (2) All local questions must be dealt with locally and finally in localities. (3) There must be no delay in settling. The employers considered the men's proposals in private, and arrived at the following resolution: "That the employers are not prepared to enter into any distinct agreement with any single trade, covering all general questions which are common to shipyard workers, but if the Boilermakers' Society are prepared to become a party to the general agreement covering such questions, then the employers will be prepared to enter into a subsidiary agreement with them for questions special to their trade, keeping in view the desirability of speeding up the final settlements of these questions." The men's representatives, after considering this resolution, sent a deputation to the employers to ask (1) what the employers proposed to do with respect to the proposals which they had made regarding a national agreement, and (2) if the employers would define to some extent the terms of their proposed subsidiary agreement. It was also pointed out by the men that, in view of the votes of their members against entering into a joint agreement with other trades, and in favour of having an agreement entirely their own, they could not accept the suggestion that they should adopt the general shipyard agreement arrived at between the employers and the other trades without first going back to their members. They had no power to do so. The matter was discussed, however, for some time, and ultimately it was agreed to adjourn the conference to a date to be fixed later, so as to allow both sides to give the points which had been raised full consideration. After the discussion of the proposed new agreement had been closed the men's representatives put in a claim for a general advance of 5 per cent. on the wages of members of their society employed in shipyards. To this the employers replied that they could not deal with the question of a general advance of wages with reference to one trade union only, but must deal with a question of that kind as it affected the whole industry

Effect of Sodium on Aluminium.—According to "The Brass World," sodium, when present in metallic aluminium, causes it to corrode rapidly, depending upon the amount present. When aluminium was made by reducing the chloride by metallic sodium, the aluminium obtained contained considerable, and explains why some of the early samples of this metal turned white so rapidly when exposed to the air. Aluminium produced at the present time contains very little sodium as an impurity.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL. 1911.

Washing out and filling locomotive boilers with hot water. Groom. 24768.

Speed indicators. Low. 25106.

1912.

Means for imparting rotation to a shaft. Hallsworth. 210.

Variable-speed power transmission. Pletts. 676.

Turbine. Brown. 3339.

Method of extracting the natural moisture from bog peat. Elborne & Godpal. 3367.

Method of extracting iron from iron sands. Elbourne & Godsal. 3368.

Apparatus for heating boiler feed water. Morison. 3499.

Hydraulic rams, fitting them to serve as air compressors. Hill, Hill, & Hill. 3507.

Motor vehicles. Heide. 3550.

Valve mechanism of internal combustion motors. Clifton. 3589.

Means for fastening, repairing, and strengthening machine belting. Moon. 3786.

Flexible shaft couplings. Smith & Saunders. 3853.

Regulating devices for pumps. Warwick Machinery Company (1908). 3866.

Clutches for the transmission of power. Ionides, Goddard, and Jarvis. 3957.

Fluid motor. Neighbour. 4068.

Valves for internal combustion engines. Wilee. 4191.

Attachment for carburetters of internal combustion engines, to give a rich mixture for slow running. Badcock. 4343.

Regulation of the temperature of the cooling fluid of internal combustion engines. Sonck. 4494.

Aeroplanes and airships. Holloway & Howden. 4676.

Steam boiler furnaces. Groves & Dalrymple. 5000.

Engine starter. Roth & Murphy. 5388.

Internal combustion prime movers. Bowles & Durtnall. 5394.

Twist drills and reamers. Brundrett. 5471.

Silencers or exhaust boxes for internal combustion engines. Sharpe. 6178.

Devices for detecting incomplete combustion or black smoke in the furnaces of boilers. Carr. 6520.

Means for indicating and limiting the overheating of gas engines. Hueckel. 8435.

Water tube boilers. Aitken. 8967.

Steam superheaters for marine boilers. Robinson. 9098.

Reciprocating engines. Browne & Nickols. 9176.

Automatic grease cups. Thomsen & Kirkham. 9201.

Apparatus for use in the analysis of gases. Harger. 9623.

Automatic couplings for railway vehicles. Smith. 10380.

Steam turbine glands. Baumann. 10567.

Utilising the rise and fall of the tide for obtaining and distributing motive power. Southard. 11731.

Valve operating gear of internal combustion engines. Price and Price. 11892.

Milling, facing, drilling, and boring machines. Kearns, Burton, and H. W. Kearns & Co. 12122.

Device for governing the damper in connection with the fire door in boiler furnaces. Matter. 12755.

Journal packing. Krupitschka. 13584.

Gas or fluid tight rings for engine valves. Tetlow & Miller. 13832.

Packing for piston rods. Mastin. 14075.

Compressed air motors. Schrepter. 14110.

Means for preventing the ejection of sparks and live cinders from locomotives. Notter. 14247.

Cutting gear teeth. Maag. 14455.

Combined speed meters and revolution counters. Schurmann. 14462.

Sand mixing machines for foundries. Bowdle, O'Brien, and Schmidlapp. 14711.

Device for tensioning chains. Jorgensen & Juul. 14825.

Hand or power machine for shearing and punching metal. Trice. 15320.

Gas turbines. Blake. 15379.

Tool for breaking down coal and the like after undercutting. Field. 15490.

Means for removing moisture from air and gases. Schou. 16510.

Rotary combustion engines. Tips. 16799.

Compression relief devices for internal combustion engines. Prentis. 17816.

Signalling system for indicating the position of vehicles on railways. Konig. 17969.

Motor-vehicles. Heide. 18656.

Fusible plugs for air compressors. Hodges & McCaffrey. 18680.

Apparatus for introducing fuel into the cylinders of internal combustion engines. Schenker. 18808.

Apparatus for indicating the draught of ships. McNab. 20103.

Motor driven vehicles. Strasser. 20420.

Cooling of internal combustion engines. Justice. 20649.

Steam generators. Steinmuller. 21534.

Hydraulic brakes for motor vehicles. Etablissements Lyonnais Rochet Schneider. 22369.

Propeller blade. Da Costa. 22441.

Fuel injecting apparatus for internal combustion engines. Pasel. 22618.

Apparatus for lubricating motors. Soc. Anon. le Zèbre. 22953.

Systems of hot water circulation. Forrest, Rawson, & Forrest. 23141.

Pump pistons or plungers. Allen. 24347.

Process for the production of tool steel and other high grade steels. Dellwik Fleischer Wassergas Ges. 24440.

Lubrication of internal combustion engines. Mathis. 24588.

Apparatus for evaporating and concentrating liquids. Soc. d'Exploitation des Procedes Evaporatoires Systéme Prache et Bouillon. 25458.

Metallic packing for piston rods. Copeland. 25482.

Marine turbine installations having two propeller shafts. Akt. Ges. Brown, Boveri, et Cie. 27070.

Internal combustion engines having oscillating cylinders. Addison Williamson. 27673.

Travelling grates. Sillery. 29054.

1913.

Tool or device for turning and screw threading metal. Land. 889.

ELECTRICAL, 1911.

Electrical relays. Brown. 27953.

1912.

Controlling dynamos running at varying speeds. Foster and Pocklington. 3105.

Electric railway systems. Deschamps. 3123.

Electrical resistance bodies. Cooper. 3325.

Process and apparatus for carrying out gas reactions in the electric arc. Boult. 3342.

Method of and apparatus for generating high frequency currents. Heyland. 3555.

Electric switches and the conductor connections thereto. Sheldon. 3590.

Telegraphy and telephony by submarine cables and long distance overhead lines. Schiessler. 4061.

Electrical switches. Wynne. 5462.

Electro magnetically operated switches. British Thomson Houston Company, and Garton. 5576.

Impregnation and coating of electrical apparatus with insulating material. Turner. 5856.

Electrical conduit fittings. Byng & Taylor. 6052.

Alternating current motors. British Thomson Houston Company. 9210.

Electric connection fittings. Trood & Dale. 9911.

Production of ductile iron by electrolytic means. Plauson and Tistschenko. 10882.

Apparatus for the control of electric circuits in systems employing variable speed generators. Leitner. 11175.

Brush holders for dynamos. Pintsch's Electric Manufacturing Company, and Vidal. 15471.

Secret intercommunication telephone systems. Telephonfabrik Akt. Ges. vorm. J. Berliner. 16084.

Regulating switch. Curtis. 16938.

Covering of electric conductors with plastic material. Smith and Schuter. 22534.

Electricity meters. Korting & Mathiesen Akt. Ges. 27775.

Electric switches and the conductor connections thereto. Sheldon. 30024.

The German Society of Mechanical Engineers are offering a prize of £75 for the best treatise on annoying noises caused by city and street railways, their causes, and the best means of suppressing them: also similar prizes for a work on the heating of cars by steam, for one on cranes used in locomotive shops, and one of £100 for an investigation of car springs, with designs and formulæ.

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Edited by
WILLIAM H. FOWLER
Wh. Sc., M.Inst.C.E.

Telegrams: "Scientific," Manchester.
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Electric Shock and the Earthing of Coal Cutting Machines.

An inquest held at Haughton Main Colliery during the past week, respecting the death of a man who received a fatal shock while operating an electrical coal cutter, draws attention to the avoidable risks that are too often incurred in connection with this class of machine, partly on account of the imperfect earthing and partly on account of the excessive pressures used. In the accident in question, it was clear from the evidence of the Home Office inspector that the machine was defective in both these respects. It was worked at 650 volts, and the earth conductors, it was shown, were very imperfect. The verdict of "Accidental death," and that no blame attached to anyone coupled with a suggestion that the management should reduce the voltage and adopt the other suggestions of the inspector, was, as coroner's verdicts usually are, very unsatisfactory. It transpired that the deceased wore rubber gloves, but this did not prevent the fatal shock. Possibly they were defective. In fact, with the rough wear and tear of mine work it would be difficult to maintain their efficiency, and in any case it is not fair to expect men to work with such a slender safeguard against fatality, and we quite agree with the inspector that a voltage which requires the use of gloves is obsolete for mining work. It is possible to work such machines satisfactorily with 200 volts, and it should, therefore, not be carried to the coal face at a higher pressure, having regard to the rough usage which mine work entails, and the difficulty of ensuring adequate supervision of electrical connections. How imperfect these often are was pointed out by Mr. Nelson, H.M. Electrical Inspector, in the Home Office report for 1911, a summary of which we gave recently (see p. 61 ante). Referring to the fatalities there recorded he observed that "two-thirds of the total number might have been avoided by the provision of proper earth connections," and that "nearly one-half of the total number of electric shock accidents that have occurred in mines since the

beginning of 1905 were due to the same cause." In view of this fact it is not surprising that men engaged in the working of electrical coal cutters should view them with a good deal of mistrust, and is regrettable because it tends to hamper electrical progress. The making of a satisfactory "earth" below ground is not always as easy as it might appear to those who have not specially studied the matter. We have previously touched on this point, but in view of the ignorance that prevails it may be advisable to allude to it again, in order that the necessary precaution may be properly appreciated. In the first place two cables are led to the machine, one for the flow of current and the other for its return, and so long as the machine framework and its metallic connections (which, if it is mounted on rails, may extend to a considerable distance) remains insulated from the circuit, no risks of shock through touching the machine framework or rails can be incurred. Owing, however, to a variety of causes, such as the accumulation of coal dust, carbon, oil, &c., the risk of the framework becoming alive through contact with some part which is carrying current is always present, and this risk must be guarded against, and the only way to do this is to so earth the machine that such an accidental leakage is innocuous. The difficulty in many cases is to make this earth effective owing to the dryness of the coal seam and its comparatively insulating character. In such cases if leakage occurs the whole of the machine and its connections may become charged to the potential of one of the cables, and if the other cable happens to be earthed in any point in its course it only requires a connection to be made between the machine frame, &c., and earth to cause current to flow from one to the other. This connection may easily be made by some person standing on a damp spot and accidentally touching the machine, with possibly fatal consequences. If the machine is perfectly earthed the risk is, of course, obviated because the leakage then passes through the "earth" and not through the man. In damp pits there is no difficulty in making a perfect "earth," but in dry ones the difficulty may be serious, and in such cases nothing short of a direct connection and a wet sump can be considered effective. We cannot too strongly impress on electrical engineers in collieries that the connection of a machine to an earth plate in the adjoining strata *may not* be sufficient, since the strata itself may be insulated. An electrical expert can, by well-known methods of testing, which we need not here go into, determine whether the earth is a satisfactory one or not, and such tests should, as a matter of routine, be made periodically.

The Imperial Standards of Weight and Measurement.

THE report of the Board of Trade on the administration of the Weights and Measures Acts contains some observations and comparisons between the imperial standard pound and standard yard, and the four official copies deposited with the Royal Mint, the Royal Society, Greenwich Observatory, and the Standards Department respectively. These are interesting to engineers as showing the difficulty in securing uniformity and immutability of standards for even a moderate time, and when every care and refinement are employed. The tests of the standard yard copies also reveal differences which are quite appreciable and which we should have hardly expected, the Royal Mint copy, for instance, being 23 millionths of an inch short of the standard, the Royal Society copy 49 millionths short, the Greenwich Observatory copy 43-millionths short, and the Standards Department copy 215-millionths short. These differences, surprising as they doubtless will be to engineers familiar with modern methods of measurement, are to some extent understandable and may be due to the constructional difficulties in securing exactitude when the copies were made, but it does not account for the curious alterations in length that are stated to have taken place during the last ten years, and which, we presume, can only be attributable to atomic changes in that period in the copies themselves. These changes, again, it will be noted, are not uniform, nor, in the case of three of them, can they be regarded as minute. The Mint copy has only lengthened one-millionth of an inch in the ten years, but the copies at the Royal Society and at Greenwich have increased 47 and 42 times this amount respectively, and it is not easy to understand how this enormous disparity in change has been brought about, and even more difficult to account for the fact that the copy at the Standards Department has not lengthened like the other three, but actually shortened by 23-millionths of an inch during the same period. The changes in the standard copies of the pound weight are as equally puzzling as those observed in the standards of measurement, and display also the same obliquity as regards their nature, for while the Royal Mint copy is 364 hundred-thousandths of a grain and the Royal Society copy 68 hundred-thousandths of a grain heavier, the copies at Greenwich and at the Standards Department are respectively 84 hundred-thousandths and 261 hundred-thousandths of a grain lighter. Coming to the changes in the mass of these copies in the last decennial period we find that, whereas the Royal Society copy sustained a loss of 6 hundred-thousandths of a grain, the three copies at the Mint, Greenwich, and Standards Department actually gained in weight, the amounts being 18, 79, and 23 hundred-thousandths of a grain respectively. No explanations are offered for these curious alterations in mass, and it seems difficult to suggest one, for if oxidation be put forward as a possible cause of increase, why should it only apply to three of them, and the fourth actually suffer a decrease in weight?

ALTERNATING-CURRENT MAGNETS.

IN the course of a paper on "Alternating-current Magnets," by Prof. E. Wilson, read before the Physical Society of London, the author said that it followed from the well-known law of pull of an electromagnet that if the magnetic field alternated between positive and negative values the pull was unidirectional and intermittent. Unless means were provided to reduce the consequent chattering and vibration, the magnet was rendered useless. In the present experiments a phase-splitting device had been adopted, and consisted in surrounding a portion of the pole-piece of the magnet with a short-circuited coil. The portion of the pole-piece so surrounded was sometimes said to be "shaded," and the coil referred to as a "shading" coil. The effect of this coil was to alter, not only the relative amplitudes, but the phase of the magnetic fields passing through the shaded and unshaded portions of the pole-face. The magnet used in the experiments varied the length of its gap when in action, and the influence of the gap length upon this phase-displacement had been studied. When the resistance of the shading coil was such that the magnetic induction B over the whole face was substantially uniform and the gap closed, the phase-displacement was 72 electrical degrees (360° = 1 period). A gap length of 0·15 cm. reduced the phase-displacement to 18°, and consequently the minimum or "hold on" pull dropped. This minimum or "hold on" pull was, of course, smaller than the average, and had to be taken into consideration in the design of the magnet. The arrangement of the shading coil above described was very effective in preventing vibration and chattering when the magnet was closed, and rendered the alternating-current magnet a practical success. With constant alternating voltage impressed upon the magnetising coils of the magnet the net pull exerted diminished rapidly at first as the gap length increased, and tended to become more nearly constant. The R.M.S. amperes, on the other hand, steadily increased as the pull diminished owing to the increase in the gap length. The observed net pull in the case of the magnet experimented upon was less than the calculated average pull, varying from 83 to 59 per cent. as the gap length varied from 0 to 1 cm.

INSTITUTE OF METALS.

THE annual general meeting of this Institute was held at the Institution of Mechanical Engineers, Storey's Gate, London, on Tuesday and Wednesday last. On the Tuesday the annual report of the Council was presented, which stated that the past year marked a period of material development in the activities of the Institute, and a slight growth in the membership. Owing to ill-health, the President, Prof. W. Gowland, F.R.S., Assoc. R.S.M., had been obliged to relinquish the presidential duties before the completion of his term of office, and the Council expressed not only their sympathy with Prof. Gowland in his illness, but their appreciation of his valuable work for the Institute. In the absence of the President, Prof. A. K. Huntington, Assoc. R.S.M., as President-Designate, was appointed Acting-President by the Council. Referring to the work of the corrosion committee the report states that considerable progress had been made in the investigation of the causes of corrosion of tubes of the four types of alloy selected by the Committee, namely 70:30 brass, Admiralty mixture, lead-bearing brass, and Muntz metal. 12 tubes of each alloy had been tested in the special condenser plant for nine months, *i.e.* from April to December, 1912. Three tubes of each composition had been withdrawn for detailed examination; this, however, had not yet been completed. A preliminary examination had shown that a small amount of corrosion, such as that usually met with in tubes that had failed in practice, had occurred in some of these tubes, but had not penetrated to any considerable depth. All the tubes had been found to be covered with a scale of composition similar to that typical of those used in the mercantile marine. Investigation on these tubes was still proceeding. The plant itself was closed down temporarily on December 31st, 1912, pending the supply of further funds for working expenses, which amounted to about £100 per annum. It was highly desirable that the experiments with this plant should be continued at the earliest opportunity, and this would be done as soon as the necessary funds were forthcoming.

An extensive scheme of laboratory experiments had been devised with the object of elucidating the nature of reactions which took place during the processes of corrosion and scale formation. It had been found necessary to continue a number of the experiments for periods of several months, as the collection of data was necessarily slow. Hitherto it had not been possible to devise any satisfactory "acceleration" test, so work in this direction had been abandoned for the present. A considerable number of badly-corroded tubes had been sent in for examination by various shipping firms and manufacturers, and afforded useful information. The Investigator was now desirous of obtaining a number of tubes that had endured exceptionally long service in marine or land condensers.

The five Standing Committees, known respectively as the Abstracts Sub-Committee, the Corrosion Committee, the Finance and General Purposes Committee, the Library and Museum Committee, and the Publication Committee, had met regularly during the past year, and several occasional committees had been appointed by the Council for the consideration of special matters.

The Special Committee appointed by the Council to discuss with Dr. Beilby, the proposed research, as originally suggested in his May Lecture, 1911, held meetings during the year, and Dr. Beilby was invited to read a paper elaborating his suggestions at the London Meeting of the Institute in September, 1912. This paper was entitled "The Solidification of Metals from the Liquid State," and was regarded by the Committee as the basis of a research into this subject. The Committee appointed Dr. Cecil H. Desch their Investigator, his remit being as outlined in Dr. Beilby's paper, and his report was expected to be made at the next autumn meeting of the Institute. Dr. Beilby had kindly placed at the disposal of the Council a sum of £100 to be awarded as an honorarium in connection with the research.

As a result of a suggestion contained in Dr. Rosenhain's Paper "A Note on the Nomenclature of Alloys," read at the Annual General Meeting in January, 1912, the Council appointed a Nomenclature Committee to consider the renaming of certain of the non-ferrous alloys. It was thought desirable by the Council that the Committee should number among its members officially appointed representatives of other institutions, and this had been arranged.

In connection with the International Congress of Mining and Metallurgy, Applied Mechanics, and Practical Geology, 1915, Prof. W. Gowland, F.R.S., Sir Gerard A. Muntz, Bart., Dr. W. Rosenhain, B.A., and Mr. G. Shaw Scott, M.Sc., were appointed by the Council to act as the representatives of the Institute. The Council had guaranteed the sum of £50 towards the expenses of the Congress.

In connection with an enquiry by the Dominions Royal Commission into the supply of non ferrous metals and ores in this country, the Council had appointed the following committee, with power to add to their number from amongst the members of the Institute. Mr. G. A. Boeddicker (hon secretary), Mr. W. Murray Morrison, Sir Gerard A Muntz, Bart., Mr. Leonard Sumner, M.Sc., and Prof. T. Turner, M.Sc.

The report of the honorary treasurer, Prof. Thomas Turner, M.Sc., for the year ending June 30th, 1912, showed that the finances of the Institute were in a satisfactory state. The financial year opened with a credit balance of £456. 5s., and closed with a balance, also to credit, of £563. 10s. 11d., showing an increase of £107. 5s. 11d. This was especially gratifying in view of the fact that the legal costs of the incorporation of the Institute were paid during the financial year. During the year £269. 4s. 3d. was expended on the corrosion plant and its working expenses. The balance on July 1st was only £47. 7s. 6d., which had since been practically all expended. It was intended to continue these experiments for two or three years longer, and for this purpose an income of about £100 per annum would be required.

The results of the ballots for the Council for 1913 and for the election of new members was declared, after which the president, Prof. A. K. Huntington, delivered his inaugural address. In the evening the fourth annual dinner of the Institute was held at the Criterion Restaurant, Piccadilly Circus.

The following day (Wednesday) was devoted to the reading and discussion of papers, abstracts of which are presented herewith.

Metal Filament Lamps.—This paper, by Mr. Alexander Siemens, summarised the history of the use of metal filaments in glowlamps. Owing to the uneconomical working of carbon filament lamps, endeavours were made to replace carbon by one of the rarer metals, which could sustain a higher temperature than carbon without disintegrating. Auer was the first to utilise Osmium, prepared by a squirting process, and his methods were followed by several other inventors experimenting with various metals. The first lamp to have actually drawn metal wire as its filament was the Tantalum lamp manufactured by Siemens & Halske, Berlin. They also succeeded in drawing an alloy of tungsten and nickel, but before that process was perfected, the General Electric Company, of Schenectady, patented a process to make pure tungsten ductile, which was described in the paper.

The Corrosion of Distilling Condenser Tubes.—This subject was dealt with by Mr. Arnold Philip, B.Sc. (Admiralty Chemist). Main and auxiliary condenser tubes, he said, became corroded on the sea water side; corrosion on the steam side of the tubes practically never occurred. In distilling condensers the reverse of this was the case. No corrosion occurred as a rule on the sea water side of the tubes, but frequently occurred on the surfaces exposed to the steam. The absence of corrosion of the sea water side in distilling condensers was, he considered, apparently due to the facts that: (1) The sea water flowed outside the tubes, which tubes were generally placed vertically; on this account no particles of carbon, ash, &c., could find a lodgment on the surface of the tubes on the sea water side, and thus what the author had shown to be one of the most important causes of corrosion was absent. (2) The tubes were usually in direct metallic connection with the casing being expanded directly into the tube plates; this permitted the full galvanic protective effect of any protector bars, and of the casing itself when this was wholly or partially of iron or steel. The corrosion on the steam side of distilling condenser tubes was, he observed, due to hydrochloric acid in the steam. The origin of the hydrochloric acid was the dissociation of salts contained in sea water, probably magnesium chloride. This dissociation only

took place to any noticeable extent when the primary steam tubes in the evaporators projected above the surface of the brine which was being boiled. The same distilling condenser used with two evaporators, one of which had steam coils projecting above the brine surface, and the other drowned steam coils, produced distilled water containing hydrochloric acid in the former case, but free from this acid in the latter case. The effect of the acid containing steam from the evaporator was to corrode the surface of the distilling condenser tubes, and the distilled water obtained contained not only free acid but also chlorides of copper, zinc, and (if tin-coated tubes were used) also tin. The presence of copper in the distilled water was particularly objectionable both for potable uses and also because when passing into the boilers it tended to set up further corrosion and pitting on the steel surfaces.

The way to avoid these troubles was, he said, to use distiller evaporators which contained completely drowned coils. A palliative to prevent copper passing into the boilers with the distilled make up water, if this contained copper due to a faulty form of evaporator being used, was to pass the distilled water through a zinc scrubber which removed the copper. Chemical methods for detecting and measuring minute amounts of free hydrochloric acid in the distilled water obtained from distilling condensers were described.

The Corrosion of Aluminium.—This paper, by Mr. G. H. Bailey, D.Sc., dealt essentially with the action of water and salt solutions on aluminium. In the course of the investigation the effects of variation in the nature of the waters used and in the concentrations of the salt solutions had been examined. A large number of results were given illustrating also the dependence of corrosion on temperature and on the quality of the aluminium employed. The author also gave a method by which reliable measurements of the rate of corrosion could be made, and from an examination of the experimental evidence arrived at the following conclusions: That aluminium of high purity was less readily acted upon than that of lower purity, and that the presence of sodium and copper in the metal increased the rapidity of corrosion. Well-annealed metal was also more resistant to corrosion than unannealed metal. He found that in general the corrosion of aluminium was a process of oxidation, and that, as a matter of fact, metal exposed for several months to water or salt solutions from which the dissolved air had been expelled underwent no corrosion whatever. The normal course of corrosion (excluding the action of acids and alkalies) was thus a transformation of aluminium into alumina, which separated out as a flocculent precipitate without any of the aluminium passing into solution.

The Microstructure of German Silver.—For the purpose of this paper, which was presented by Mr. O. F. Hudson, M.Sc., samples of German silver, which had been annealed for varying lengths of time at a temperature of 7,000° C., were examined microscopically. The alloys, which consisted of a single solid solution, required many hours annealing at this temperature to bring them to a condition of true equilibrium when the solid solution appeared to be perfectly homogeneous. German silvers when annealed thus commonly possessed a characteristic "cored" structure which was independent of the normal twinned crystalline structure also seen. The rather coarsely crystalline structure which resulted from the long annealing necessary to remove the "cores" was not in itself a sign of a deterioration in rolling qualities. The results of tests on samples annealed for various times at temperatures up to 1,000° C. showed that, under laboratory conditions, the rolling qualities of good German silver were not impaired by severe annealing. Hardness tests, using the sclerescope, showed that prolonged annealing, accompanied by pronounced crystal growth, did not lead to any decrease in hardness beyond that due to the normal annealing operation.

Quantitative Effect of Rapid Cooling upon the Constitution of Binary Alloys.—The author of this paper, Mr. G. H. Gulliver, B.Sc., showed how to calculate the proportions of the constituents of a rapidly cooled binary alloy by means of the information obtained in the usual manner from very slowly cooled alloys. The importance of the subject was due to the fact that the constitution of a cast alloy cooled at ordinary rates lay between that of the very slowly cooled and that of the very quickly cooled mixture, so that its limits of variation with change in the rate of cooling could be now specified. The method of calculation was applied to the lead-rich alloys of the lead-tin series. The proportion of eutectic in a just solid alloy, the proportion of liquid and of solid in an alloy at a temperature between its freezing and melting points, and the rate of solidification of an alloy at a given temperature, when slowly and when rapidly cooled, were found numerically. The apparent form of solidus obtained from a rapidly cooled alloy was given, together with the variation in the apparent position of the saturation-point which accompanied variation in the rate of cooling. It was shown that the position of the apparent saturation-point depended not only upon the rate of cooling, but still more upon the composition of the alloy, and further, that the proportion of eutectic present in a rapidly cooled alloy was sensibly independent of the curvature of liquidus or solidus. The paper was accompanied by a number of diagrams which clearly showed the differences between the conditions which prevailed during slow and rapid cooling respectively.

Practical Heat Treatment of Admiralty Gun-metal.—As difficulty often arose in producing gun-metal castings to fulfil specified physical tests and withstand hydraulic pressure, Messrs. H. S. Primrose and J. S. G. Primrose, the authors of this paper, described their experimental work with the object of finding a simple and reliable method of improving this commonly used industrial alloy so as to obtain the highest possible strength and elongation accompanied by greater soundness and homogeneity of the metal. They found that even in the absence of blow-holes, which constituted the commonest source of unsoundness, cast gun-metal behaved unsatisfactorily under hydraulic tests due to the presence of microscopical pores formed between two constituents of widely different properties.

A series of tests were carried out to investigate the practical value of various kinds of heat treatment, such as reheating, quenching, and annealing test bars of gun-metal, conforming to the Admiralty specification of 88-10-2, which had been cast in sand and chill moulds and then cooled at different rates. The sets of normal and treated bars were tested physically and examined microscopically to determine exactly the effect of quenching from different temperatures, and also of annealing for various periods of time at different temperatures. The first set of tests made showed no improvement was effected by reheating and quenching the bars, as the strength and elongation fell off rapidly as the temperature was raised. This result was unexpected, as it was known that pure bronze was increased in strength by similar treatment.

More satisfactory results were obtained by simply annealing the metal at various temperatures, followed by moderately slow cooling, as this was found to considerably increase both the tensile strength and the elongation. The most marked improvement was found to be produced by annealing the bars for half-an-hour at a temperature of 700° C., as the physical tests showed lower results both above and below this critical point. The time factor was also investigated and found to be critical for the ⅞in. thickness of metal used at 30 minutes, although only a slight improvement resulted after annealing for 20 minutes, and a slight diminution in strength occurred if annealing was too long prolonged.

The practical applications were discussed, and examples quoted from practice in which material not otherwise defective failed under the hydraulic test, due to water sweating through the microscopic pores, but after suitable annealing conformed to the most rigid tests. The increased homogeneity of the metal after the heat treatment was shown to be due to the absence of eutectic segregations from the microstructure, leaving only the strongly-interlocking crystals of alpha solid solution of the tin and zinc in the copper. It was anticipated that this heat treatment would minimise corrosion troubles.

Tosi Turbines for Italian Warships.—The Tosi turbines fitted in the Italian "scouts" lately built at Naples have, we learn, given excellent results at their trials, in which the boats made an average of 35 knots during a three hours' trial, instead of the contracted speed of 30 knots in ordinary trim, and steamed 32 knots with the maximum load on board. The fuel consumption results were also satisfactory.

MECHANICAL GEARING FOR THE PROPULSION OF SHIPS.*

BY THE HON. SIR CHARLES A. PARSONS, K.C.B., D.SC., F.R.S.

THE subject of the application of steam turbines with mechanical gearing to ship propulsion has already been brought before the notice of this Institution in papers read by the author in 1910 and 1911. These papers described the experimental installation in the cargo steamer "Vespasian," the successful results obtained with which have since that time led to considerable development in this type of propulsion. It is the object of the present paper to give an account of the progress that has been made up to the present time.

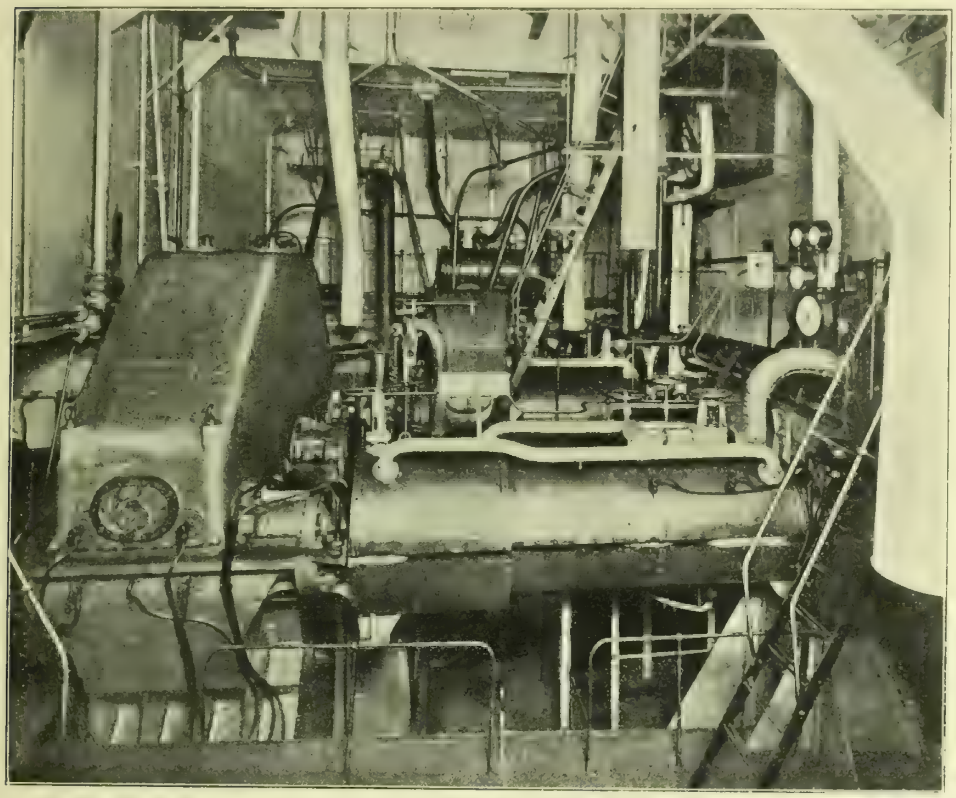


FIG. 1.—ENGINE ROOM OF S.S. "CAIRNROSS."

Geared turbine propulsion is in this country now well advanced beyond the experimental stage. There are already in actual service cargo steamers, Channel steamers, and warships, together representing a total of about 26,000 h.p. developd by steam turbines and transmitted through mechanical gearing, and there is at the present time under construction turbine machinery and mechanical gearing representing a transmission of over 120,000 h.p., including two installations of over 20,000 h.p. each.

Geared turbines have been fitted in two Channel steamers for the London and South-western Railway Company's service between Southampton and Havre, the s.s. "Normannia" and s.s. "Hantonia," of 1,900 tons displacement, having a shaft horse-power of 5,000 at a service speed of about 18 knots. These installations were fully described in a paper read before this Institution by Prof. J. H. Biles in 1912. They continue to show an economy, as compared with other turbine steamers on the same service, of about 40 per cent., due partly to increased efficiency of turbines, partly to increased efficiency of propellers with the lower revolutions adopted, and partly to improved form of vessel incidental to the reduction in boilers and the adoption of twin screws. The "Normannia's" gearing has been recently inspected after steaming over 26,000 knots, and was found to be in perfect condition; no wear whatever can be detected.

Geared turbines have also been installed in three Channel steamers for the Indian Ferry Service between India and Ceylon, in accordance with designs and specifications prepared by the late Sir William White. The first of these, the s.s. "Curzon," has successfully passed her speed trials and considerably exceeded the speed guarantee undertaken by the builders of the vessels and propelling machinery, Messrs. Inglis & Co., Glasgow. The reduction gear was made by the Parsons Marine Steam Turbine Company.

A cargo steamer built for the Cairn Line by Messrs. Doxford, Sunderland, has been recently fitted with an installation of geared turbines (see Fig. 1), similar to that adopted in the "Vespasian," consisting of two turbines, a high pressure and a low-pressure turbine in series, capable of developing about 1,600 h.p., which is transmitted through mechanical gearing to a single propeller shaft at 63 revs. per minute, the speed of the vessel being about 10½ knots. It is interesting to notice that a coal consumption trial has been made with this ship running side by side with a sister ship, the s.s. "Cairngowan," with exactly similar boilers and propeller, but with triple-expansion reciprocating engines, the coal supplied being of the same quality and measured in the same way on both ships, and the geared turbine ship has shown a saving of 15 per cent in the coal consumption.

So far no limit in regard to the surface speed of the teeth has been discerned, and there is no evidence of any limit to the power that can be transmitted by mechanical gearing with gear wheels suitably designed. It appears that this type of propulsion can be adopted with advantage in all classes of work, ranging from low-speed cargo steamers to high-speed destroyers and battle-ships and liners of large powers, and there can be little doubt that it will be extensively employed for all classes of ships in the near future. A few illustrations are given of typical arrangements of geared turbine machinery. Fig. 2 shows an installation suitable for a destroyer of about 20,000 h.p., with twin screws at 440 revolutions per minute. It will be seen that the installation consists of a high-pressure and a low-pressure turbine driving each shaft, and an additional cruising turbine geared with one of the shafts for employment at low speeds.

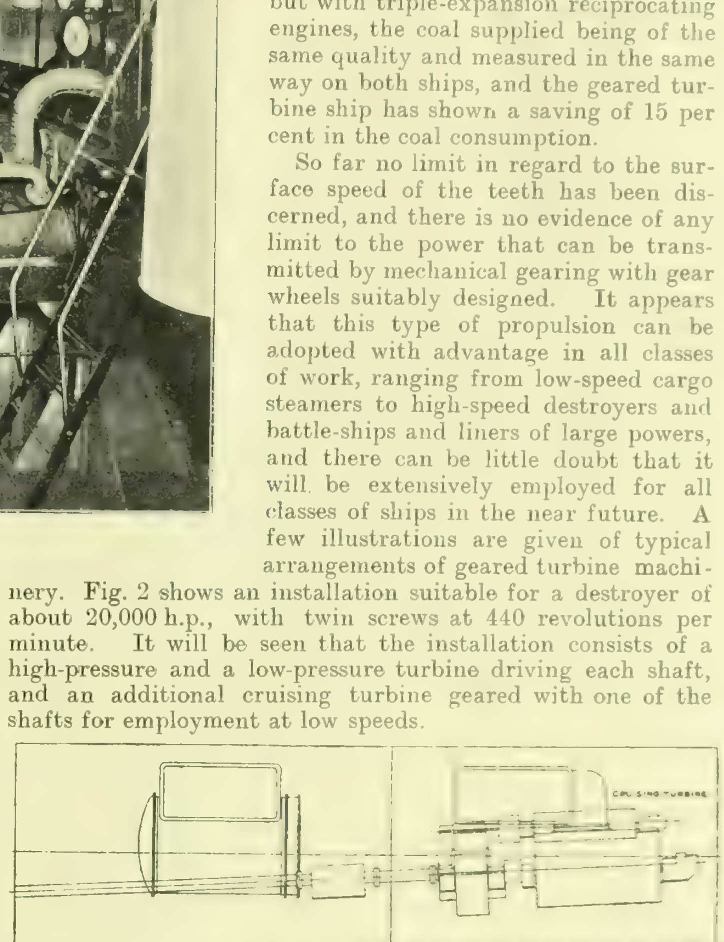


FIG. 2.—ELEVATION AND PLAN OF TYPICAL INSTALLATION OF GEARED TURBINE MACHINERY FOR A TORPEDO BOAT DESTROYER.

Fig. 3 illustrates a design for a battle-ship of about 40,000 h.p., with four shafts at 200 revolutions per minute. In the arrangement illustrated there are two turbines geared to each shaft, the turbines on the two shafts on either side of the ship being arranged in the well known 4-cylinder triple formation, each group consisting of a high-pressure, an intermediate-pressure, and two low-pressure turbines, an arrange-

* Paper read at the spring meetings of the fifty-fourth session of the Institution of Naval Architects, March 13th, 1913.

ment which leads to a high efficiency both at full power and at cruising speeds. Fig. 4 shows a further design for a battleship of about 60,000 s.h.p., with geared turbine machinery on four shafts, which also includes an additional set of small turbines and gearing for use when cruising. In such an arrangement the gear wheels of the cruising set would be connected to the propeller shafts through clutches and the main gear wheels also clutch connected, so that whichever set of machinery was in use the other set could be entirely disconnected from the propeller shafts, and all losses from idle running avoided. This separate cruising installation would have its own small condensing plant, or could make use of the small auxiliary condensing plant usually fitted. By this means the fuel consumption per shaft horse-power at the cruising speed can be made practically the same as that at full power. Fig. 5 shows an installation of geared turbine machinery suitable for a cruiser of about 30,000 h.p. on two

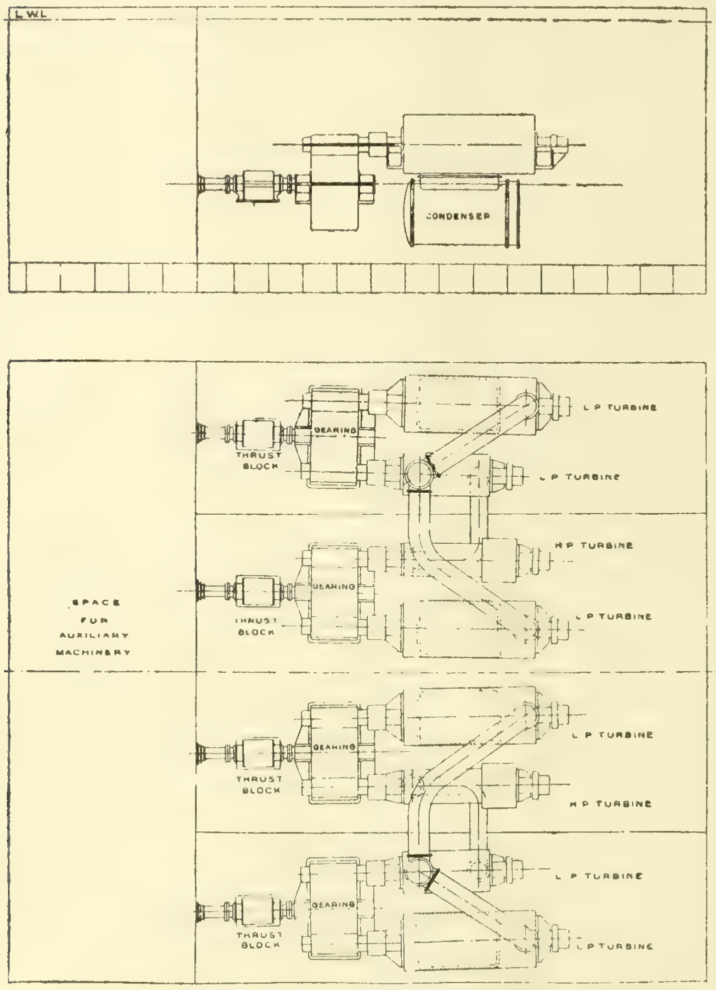


FIG. 3.—ELEVATION AND PLAN OF TYPICAL INSTALLATION OF GEARED TURBINE MACHINERY FOR A BATTLE-SHIP.

shafts at 300 revolutions per minute. Fig. 6 shows an installation suitable for a large Atlantic liner of about 60,000 h.p. on four shafts at 200 revolutions per minute.

For the purpose of observing as closely as possible the practical requirements in regard to accuracy of cutting of gear wheel teeth, two gear-cutting machines were installed in the works of the Parsons Marine Steam Turbine Company in 1910. With these machines, which were built by Messrs. William Muir & Co., Manchester, tooth faces are automatically generated by the process known as "hobbing." These two machines have, since they were installed, cut gear wheels representing a transmission of about 50,000 h.p., and the experience thus gained in this work has enabled several important improvements to be made to them. Two similar machines were installed in the works of Messrs. C. A. Parsons and Co., Heaton, Newcastle-on-Tyne, for the manufacture of geared plant for the driving of electrical generators, rolling mills, works shafting, &c.

Examination of the teeth of gear wheels which have been running for some little time, transmitting large powers, shows the work to be distributed over the teeth with fair uniformity, and confirms the opinion expressed by the author before this Institution in 1910 in his reply to the discussion on the first of the papers above referred to, that with double helical gear such devices as floating frames for the pinions or hydraulic pistons to distribute the load equally over the pinion bearings are totally unnecessary, the natural elasticity of the supporting structures providing all the accommodation necessary, assuming, of course, reasonably accurate alignment of the

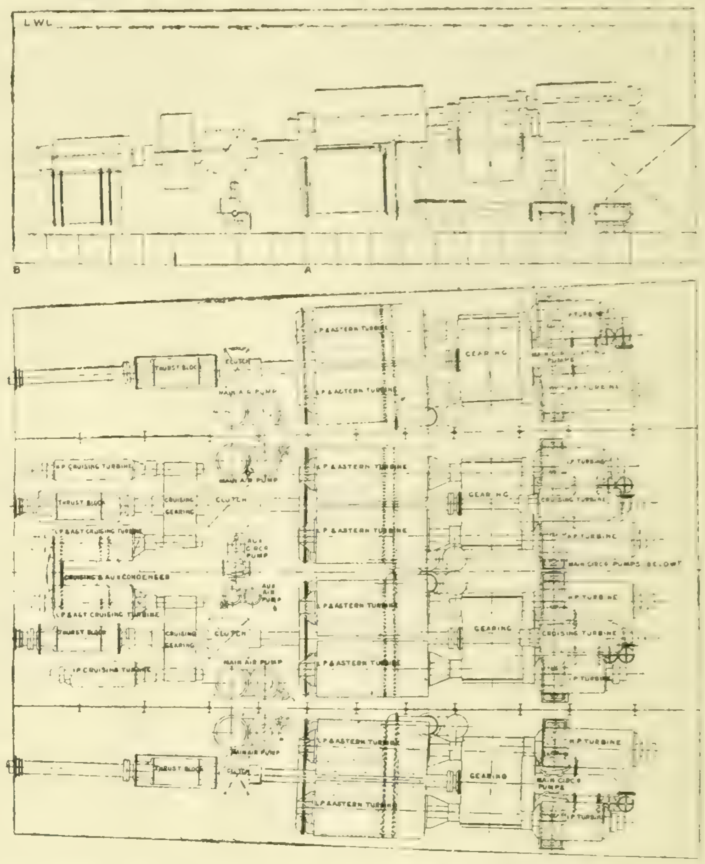


FIG. 4. ELEVATION, CENTRE SHAFT, AND PLAN OF GEARED TURBINE MACHINERY FOR BATTLE-SHIP WITH SEPARATE CRUISING INSTALLATION.

shafts. The pinions are in all cases connected to their turbine shafts by flexible couplings, which allow them longitudinal freedom, and this in itself, with double helical gears, ensures that the load is practically equally divided between the right and left hand portions of the gear.

Careful investigations have been made of the causes producing noise, with the object of removing such causes and obtaining a silent gear. These investigations show the noise to be due to slight inaccuracies in the teeth, the order of

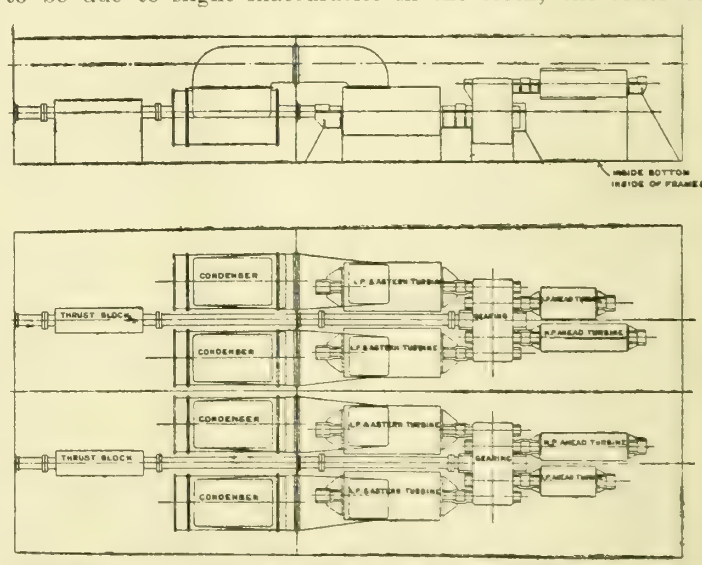


FIG. 5.—ELEVATION AND PLAN OF TYPICAL INSTALLATION OF GEARED TURBINE MACHINERY FOR A CRUISER.

accuracy required for silent gearing being higher than present gear-cutting machines are capable of affording. Fig. 7 is reproduced from a photograph of a microphone oscillograph record obtained from a double helical gear wheel by suspending over the gear case a microphone connected with an

oscillograph. It will be observed that definite notes are produced. In the particular case illustrated the frequency was found to be 160 times the number of revolutions of the wheel, and its source was traced to the parent gear of the gear-cutting machine, viz., the single worm and the 160 teeth of the worm wheel which rotated the table on which the work was mounted while the wheel was being cut. The inaccuracies of this gear were carefully measured, and found to be co-periodic with the worm wheel teeth, and to have a double amplitude of about four-thousandths of an inch.

In the case of the gear wheel referred to above, as there did not appear at the time to be any means of removing the

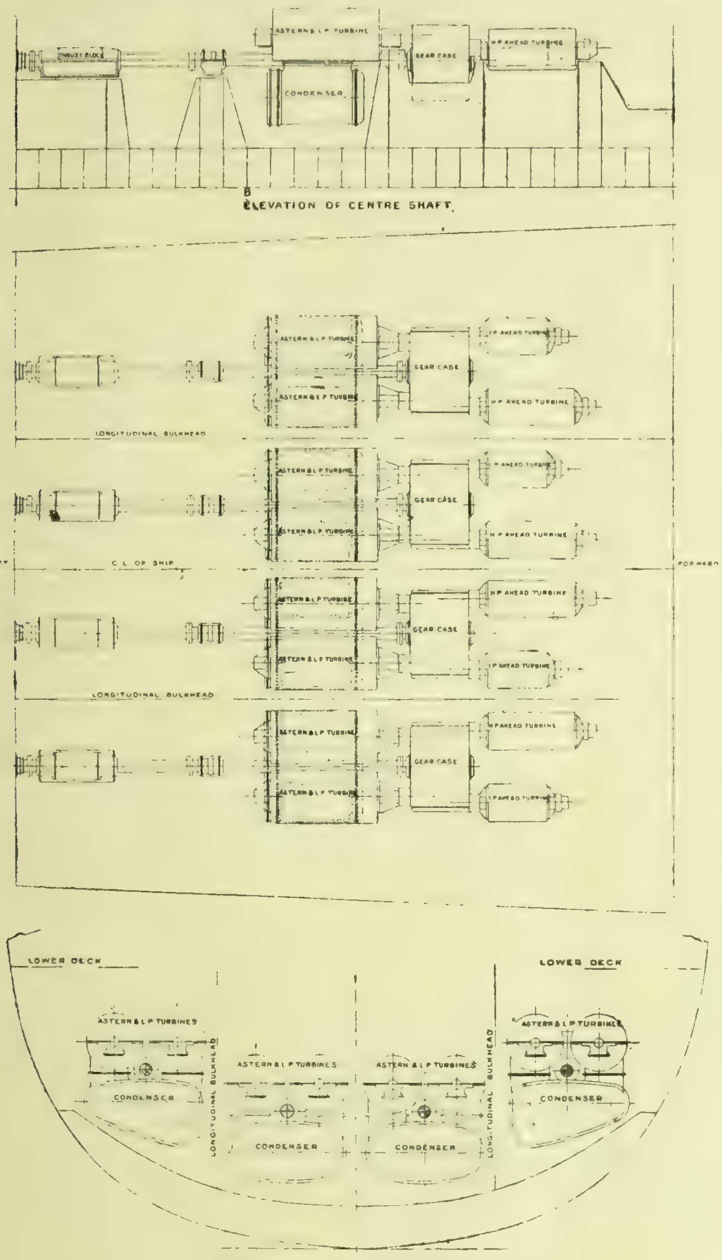


FIG. 6.—TYPICAL INSTALLATION OF GEARED TURBINE MACHINERY FOR A LARGE ATLANTIC LINER.

irregularities from the teeth, and very silent running was desired in this instance, stiff springs were fitted above and below the bearings, having a small amount of initial compression and permitting a movement of about $\frac{1}{100}$in. as the load was increased to its full value. The pinions being thus flexibly supported, noise and shock were to some considerable extent intercepted, instead of being transmitted to the structure of the gear case.

It was recognised, however, that spring supports were an imperfect remedy, the real remedy being a higher degree of accuracy in the teeth. To attain this it was necessary either to greatly increase the accuracy of the parent gear or to devise means of cutting which did not reproduce the errors of the parent gear, and, what is still more important, avoid periodicity in the residual errors. It was obvious that progress along either of these lines, or possibly along both at once, would result in valuable improvement of mechanical gearing for the transmission of large powers at high speeds.

It is doubtful whether at the present time a worm and worm wheel drive of the strength required in gear cutting machinery can be relied upon to have a higher degree of accuracy than the drive of the machine referred to above, but by the use of multiple drives, such, for instance, as several worms driving one worm wheel, it will be readily seen that these errors would, to a considerable extent, compromise each other.

An improved method of cutting gear wheel teeth has, however, been developed by the author and his colleagues, which must now be described. Primarily, it aimed at destroying the periodicity of the errors, but incidentally it also accomplished

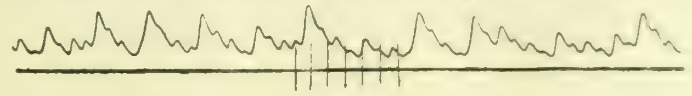


FIG. 7

a considerable reduction of the errors themselves present in the parent gear.

It will be seen that in the process ordinarily adopted in which the work is mounted on a table rotated by means of a worm and worm wheel, the latter being attached permanently to the table, the errors will be some function of the angular position of the work, and, therefore, lie in planes through the axis of rotation; and if, as is mostly the case, the errors of the parent gear are periodic, these planes will lie at equal angular intervals, and will come into mesh periodically. Now it will be seen that if the work is given a small steady advance in relation to the table, the errors, instead of lying in planes

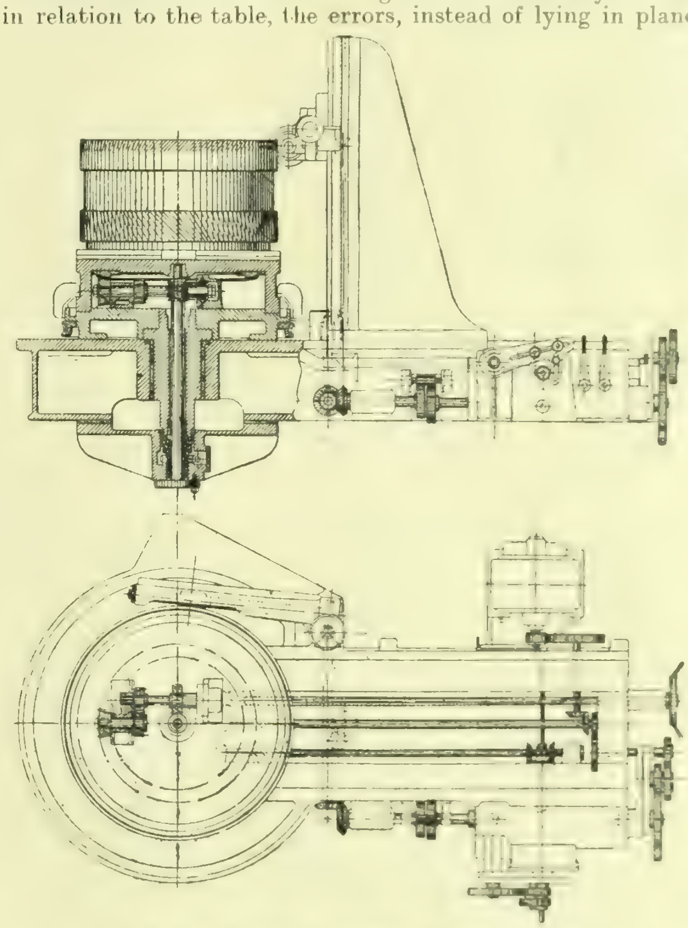


FIG. 8.—GEAR HOBBING MACHINE WITH CREEPING TABLE.

through the axis, will lie in spirals around the wheel, and that when put to work they will be obliterated and leave a true wheel.

Fig. 8 is an illustration of the adaptation of this new principle of cutting to an existing gear hobbing machine. A secondary table is mounted on the original table of the machine and given a creep in advance of 1 per cent. in relation to it by means of the train of gearing shown, the main worm driving the lower table being driven at 1 per cent. less speed, so as to secure the same rotational speed as before the creep was introduced. While the most important effect of this arrangement is that the errors in the teeth will lie in very

oblique spirals around the wheel, resulting in great uniformity in the gearing, at the same time it has also an important effect in reducing the errors themselves. The reason for this is best explained by means of the diagram (Fig. 9.)

If the periodic error in the worm gear of the original table be represented by a sine curve with a period corresponding to the teeth of the worm wheel, that is, 160 per revolution, an advance of 1 per cent. results in the phase of the error being shifted 1·616 of a complete pitch at each revolution of the work. With the cutter advancing across the wheel, the result

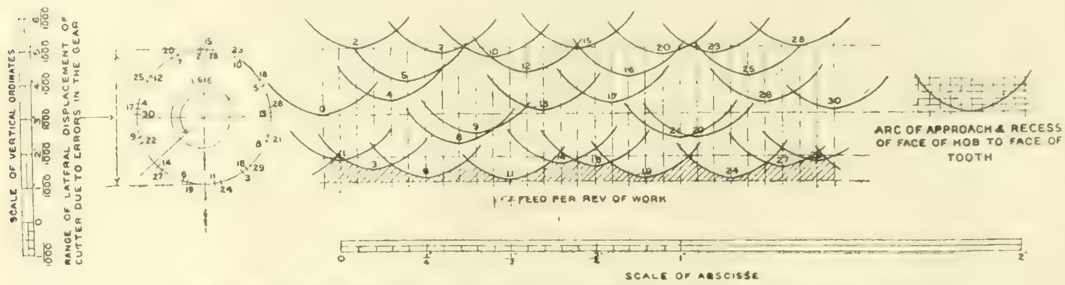


FIG. 9. DIAGRAM SHOWING REDUCTION OF ERRORS BY ADOPTION OF CREEPING TABLE FOR HELICAL GEAR CUTTING.

is a series of overlapping cuts of varying depth, the maximum depth being, say, about four-thousandths of an inch below the minimum. These have been represented on the diagram, the advance of the cutter across the wheel being taken at $\frac{1}{20}$in. per revolution, whilst the amplitude of the error, and, therefore, the position of the cutter is represented greatly enlarged in the vertical direction. It will be seen from this how the lowest positions predominate, and a series of cuspidal ridges remains of about one-fifth the magnitude of the original errors.

With the object of further illustrating the effect of this successive change of phase, one side of a slab of metal has been machined with a fly-cutter having a broad cutting edge of undulating form. The slab was advanced beneath the cutter $\frac{1}{20}$in. at a time, and at each advance it was also shifted sideways, that is, in a direction parallel to the axis of the cutter, by a definite proportion of the pitch of the undulations in the cutting edge, this proportion being the same as that adopted for the secondary table above referred to. A portion of the slab was cut in this manner, the remaining portion being cut with the slab advancing directly across the tool without any sideways motion. The result is clearly seen from the photograph (Fig. 10), the deep ridges corresponding to the undulations of the edge of the tool being replaced by smaller ridges in a network formation, as seen at A in the photograph; and if we imagine in one case two such surfaces as A to be moved across one another, and in another case two such surfaces as B in the direction perpendicular to the ridges, we obtain an idea of the effect secured by the new method of cutting referred to above, and the great advantage of the spiral distribution of the errors.

Both in this illustration and in the diagram (Fig. 9) the errors have for the purpose of illustration been

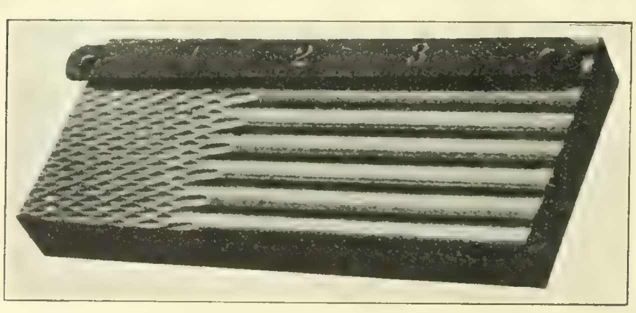


FIG. 10.

greatly exaggerated; in actual wheels the errors are so small that it is necessary to employ some form of marking such as is used with surface plates to bring out the high points on the teeth, but, even so, these high points are capable of producing sound. It will be seen, however, from the photograph that three things have been accomplished—in the first place the errors have been reduced to about one-fifth of their original magnitude; secondly, that they are spread across the wheel in such a way that periodicity is avoided; and, thirdly, that they consist of cuspidal ridges which will be easily reduced by grinding or wear and leave a practically true wheel.

ROTARY CONVERTERS.

A PAPER on "Rotary Converters" was read by Mr. N. E. Paine at a recent meeting of the Engineering Society of the Northampton Polytechnic Institute. The author said that the rotary converter was the simplest and most used machine for changing from alternating to continuous current. With the exception of the homopolar machine, the current in all electrical machines, whether generating alternating or continuous, was primarily alternating. The ratio of the continuous current to the alternating current voltage of a simple rotary was approximately constant. The alternating current voltages of a single, two and three-phase machine, assuming the continuous current voltage to be 100 in each case, were single-phase, 70·7; two-phase, 70·7; three-phase, 61·2. From these values, assuming unity power factor and no losses in the machine, the corresponding values of the currents were found:—Continuous current, 100; alternating current, single-phase 141·4, two-phase 70·7, three-phase 94·3.

The output of an electrical machine was, he observed, limited by its rise in temperature. In the rotary the heating of the armature coils was very complex. The coils nearer the slip ring connections had to carry heavier currents than the others. Thus, the heating would not be uniform. By adding to the number of slip rings, the mean rate of heating was reduced. The relative values of the outputs of rotaries fitted with different numbers of slip rings, the mean rate of heating being the same in each case (that of a continuous-current generator being taken as 100) were: Two slip rings, 85·2; three, 133; four, 162; six, 193; twelve, 219·5. It would thus be seen that single-phase rotaries were of no practical use, because the relative output was so small. Again, there was excessive heating of the coils next to the slip ring connections. These figures furnished the reason why machines were now built with six and twelve slip rings. In some cases it was necessary to vary the voltage on the continuous current side, and it was always necessary to compensate for the resistance and inductive drop on load. If the excitation of a rotary be altered there was a change in power factor, so that some other method must be adopted to vary the continuous current volts. Most of the methods used brought about a rise of the alternating current volts, and did not change the voltage ratio.

The induction regulator was really a boosting transformer on the alternating current side. In construction, it was like a polyphase induction motor, the rotor of which could only be turned through 90°. The synchronous booster consisted of an alternator, the excitation of which could be varied in series with the alternating current supply. It had the same number of poles as the rotary, and was direct coupled to its shaft, so that it was always in synchronism with the alternating current supply. Compounding could be effected as with a continuous current generator, if choking coils were provided in the alternating current lines. These coils with compounding winding had the effect of raising the alternating current volts as the load increased. If the brushes of a continuous current machine be moved forward the voltage would be altered. This was also equivalent to shifting the poles backward. In the split pole machine each pole was provided with an auxiliary pole, which when excited had the effect of shifting the magnetic centre of the pole flux forward, giving a change in the continuous current voltage. A permanent change in the voltage ratio could be brought about by connecting a few extra armature coils to the main armature winding tappings before connecting them to the slip rings.

There were three methods for starting rotary converters: (1) As a continuous current motor, which could only be done when a continuous current supply was available, such as from other rotaries in the station already running, or from an auxiliary set; (2) by a small induction motor direct coupled to the shaft, which must be fitted with a pair less poles than the rotary, so that its running speed would allow for

synchronising; (3) if the pole shoes be fitted with very heavy damping coils, the stator would approximate to the rotor of squirrel-cage induction motor, and the rotary could be started as such. Owing to commutation troubles due to the high speed, turbo-generators had not, he said, been entirely successful, so that often a rotary was direct electrically connected to the alternator of a turbo-alternator. For starting, both machines were fully excited. The rotary, being fitted with heavy damping coils, would start as an induction motor and run up to speed with the rise of frequency.

ROBINSON'S SUPERHEATER FOR MARINE BOILERS.

We illustrate herewith an arrangement of superheater for marine and similar tubular boilers, the invention of Mr. John G. Robinson, "Boothdale," Fairfield, Manchester. Fig. 1 is an end elevation and Fig. 2 a vertical longitudinal sectional

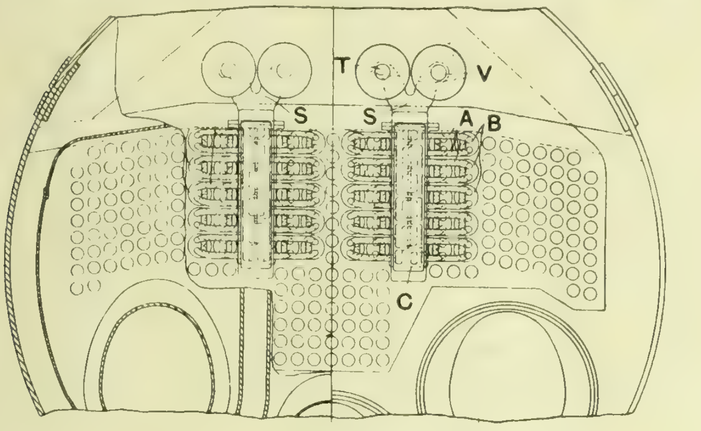


Fig. 1.

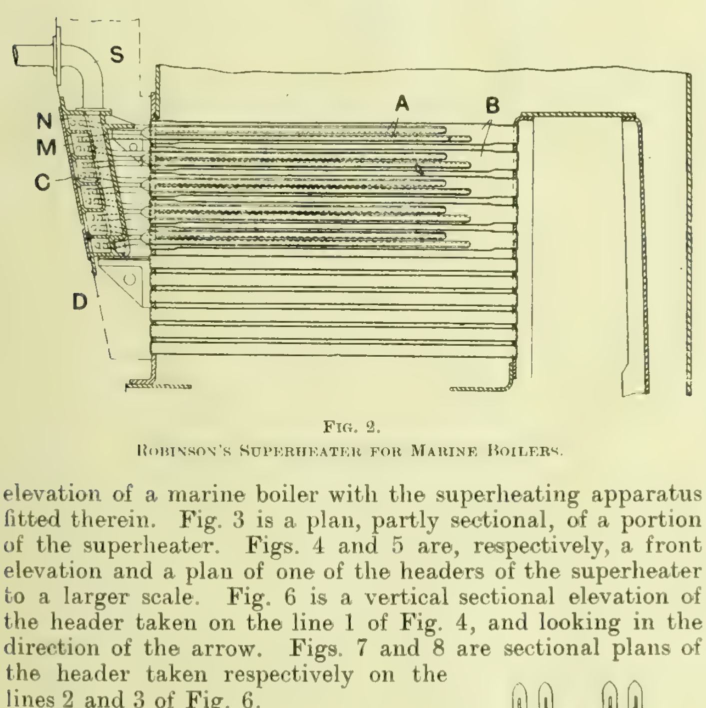


Fig. 2.

Robinson's Superheater for Marine Boilers.

elevation of a marine boiler with the superheating apparatus fitted therein. Fig. 3 is a plan, partly sectional, of a portion of the superheater. Figs. 4 and 5 are, respectively, a front elevation and a plan of one of the headers of the superheater to a larger scale. Fig. 6 is a vertical sectional elevation of the header taken on the line 1 of Fig. 4, and looking in the direction of the arrow. Figs. 7 and 8 are sectional plans of the header taken respectively on the lines 2 and 3 of Fig. 6.

Referring to the illustrations, the superheater elements or pipes A are arranged in the smoke tubes B of increased diameter. The headers C are slightly inclined, as shown in Figs. 2 and 6, and are arranged against the front wall D of the smokebox, this wall being cut away at the header so as to give easy access thereto. The headers consist of a casting comprising two longitudinal steam passages F J at the rear or smokebox tube plate side thereof and at the front or opposite side a plurality of transversely disposed steam chambers M N, these chambers alternating in the length of the header, the chambers M communicating with the passage F and being saturated steam chambers, and the chambers N communicating with the passage J and being superheated steam chambers. O is a longitudinal partition separating the passage F from the passage J. The chambers M N are open at their fronts and a removable cover plate P is provided to close these open fronts, this cover being secured in place by studs mounted in the header casting and nuts. Suitable

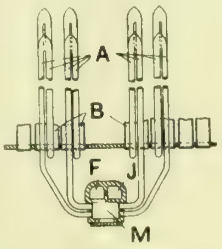


Fig. 3.

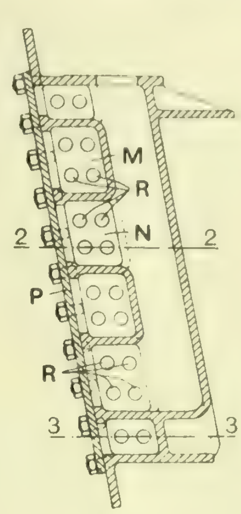
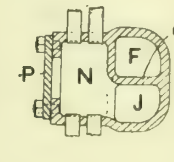
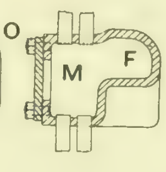


Fig. 6.

Fig. 4.





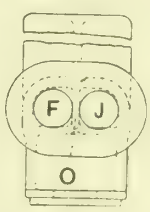


Fig. 7. Fig. 8. Fig. 5.

Robinson's Superheater for Marine Boilers.

jointing faces are provided at the front of the header to enable the cover to be secured thereon in a steam-tight manner. Flanges are provided for securing the header in position in the smokebox. In the side walls of the chambers M N holes R are provided, and into these holes the ends of the superheater elements or pipes A are expanded, the inlet ends communicating with the saturated steam chambers M and the outlet ends with the superheated steam chambers N. Pipes S connect the longitudinal saturated steam passages F to the steam spaces of the respective boilers. The longitudinal superheated steam passages J are connected to the respective engine cylinder valve chests. The pipes S comprise two ports T V, the lower end of the port T being adapted to register with the upper end of the passage F, and the lower end of the port V with the upper end of the passage J comprised in a header, the port T being adapted to be connected to the saturated steam supply and the port V to the steam pipe to the engine cylinder valve chests. Each superheater element A comprises four longitudinal runs of pipe with return bent connections.

Disastrous Explosion of Dynamite at Nobel's Works.—Six men were killed and ten others seriously injured on Monday last by an explosion of dynamite at the works of Messrs. Nobel's Explosives Company, Ltd., at Ardeer, Ayrshire. Enormous damage was caused throughout an area extending over many miles, and the explosion was heard within a radius of 20 miles. A report issued by the firm states that shortly after eleven o'clock on Monday morning an explosion occurred in a building utilised as a drying department for gun-cotton. The explosion communicated itself to three other similar buildings, and in an instant the four structures were blown to atoms. Six men who were engaged unloading the gun-cotton from two stoves met the full force of the concussion, and were instantaneously killed, while squads working in adjacent buildings were seriously injured. The four buildings were completely wrecked, while several other departments were badly damaged.

BOOK REVIEWS.

Electro-plating. A treatise on the electro deposition of metals, with a chapter on Metal Colouring and Bronzing, by William R. Barclay, A.M.I.E.E., Lecturer at the University of Sheffield, and Cecil H. Hainsworth, A.M.I.E.E., London. Edward Arnold. 7½in. by 5½in., 400 pp. Price 7s. 6d., net.

The art of electro-plating, simple as it is in its essentials, is full of subtle, disturbing factors in practice, and text-books on this subject that combine sound scientific knowledge with wide experience are comparatively few. It is this happy combination in the present instance that imprints upon it the hall-mark of excellence. There are other works more profound and abstrusely scientific, but none, in our opinion—and we speak with considerable knowledge—that more strongly appeal to the technical student and the practical man. No book can, of course, take the place of workshop training and practice, but, on the other hand, the craftsman in electro-plating can never hope to advance far unless he is at pains to master its scientific principles. The general plan of the book is framed partly on the course of lectures delivered to students in the technical classes and laboratories of the Sheffield University—the electro metallurgical department of which, we may observe in passing, is one of the best equipped in the country—and partly on the syllabus of the City and Guilds of London Institute. But it is not bounded solely by these considerations. No work of this kind would be complete that did not include some reference to the elementary principles of electrical engineering, and this the authors have presented in an admirably concise outline. The value of the various formulæ recommended for solutions, as well as the directions for carrying out the processes, are in nearly all cases those in actual use in workshop practice, and not merely derived from laboratory experiment. The book is one of the most practical text-books on the subject we know, and we cordially recommend it both to the student and the artisan.

* * *

The Design of Alternating-Current Machinery, by James R. Barr, A.M.I.E.E., and R. D. Archibald, B.Sc. London: Whittaker & Co., 9 by 6½, 496 pp. and 17 folding plates. Price 12s. 6d. net.

THIS book was intended by the late Mr. Barr as a companion volume to his "Direct-Current Electrical Engineering," but owing to his unfortunate death a certain amount of revision and correction of the proofs became necessary before publication, and it is this duty which has led to Mr. Archibald's association with it as joint author. The literature of alternating-current practice is now becoming fairly extensive, though it still leaves scope for individuality of treatment, and in this respect the work in question possesses considerable merits. Two special features of the book are the use of diagrams in various colours to illustrate different types of winding, and a number of large working drawings of actual machines which serve to give a good idea of current practice, and which should be of considerable service to those concerned with actual design apart from their obvious value in class work. A familiarity with the calculus is to some extent necessary in any treatment of the subject, though it permits of the use of diagrammatic methods to a large extent, and of this latter feature full use has been made. The book is both well printed and well illustrated, and we have every pleasure in recommending it.

* * *

The Baudot Printing Telegraph System, by H. W. Pendry. 72 illustrations. London: Whittaker & Co. 7½ by 5. 144 pp. Price 2s. 6d net.

THE chief value of this little work lies in the fact that the adoption of the Baudôt system by the British Post Office has created a demand for information concerning this ingenious invention in modern telegraphy, and though the subject is too specialised to command more than a limited range of readers we doubt not it will prove very acceptable to the section specially concerned.

A Large German Steamship. The second 50,000 ton liner of the Hamburg-Amerika Line, the sister ship to the "Imperator," will be launched on April 3rd. The vessel will sail on her maiden voyage on May 24th, after undergoing exhaustive trials.

THE DIESEL ENGINE AS MOTIVE POWER IN THE MERCHANT MARINE.*

WITH SPECIAL REFERENCE TO THE FIRST SUCCESSFUL MOTOR SHIP, "CHRISTIAN X."

BY OLE K. OLSEN.

(Concluded from page 269).

THE starting of the machinery is, as for stationary engines, by compressed air, but the operating pressure is here only 300lbs., as the compressed air is used for starting the engines as well as for stopping them when a quick reversing is desired; for instance, from full speed ahead to full speed back. In cases where the speed of the ship—by its momentum—through the action of the water on the propeller, keeps the engines running a long time after the fuel oil has been taken off, the operating air is used as a contra force to stop the engine before it is started the other way, and in order to avoid explosions the cylinder head is furnished with a safety valve.

For reversing, a horizontal cam shaft which carries the steering cams which give the valves in the cylinder heads their movements has two sets of cams, one for forward and one for back. This shaft is placed on a level with the cylinder bottom, and for the valve motion one rod is used for each valve, or four rods for each cylinder, as follows: For starting valves, air inlet, fuel oil and exhaust. These rods are at the top connected to the lever arms of the valves, and at the bottom they carry rollers which run on above-named steering cams. These rods are also linked to the cranks on the operating shaft, which is parallel to the cam shaft and runs the full length of the engine.

The reversing operation is as follows: By means of the reversing engine in the operating room—a small 2-cylinder air-driven engine which can be revolved both ways by directing compressed air to either side of the piston—the operating shaft may be turned either way, according to whether valve motion for forward or back is desired, and as the operating shaft is being turned it pulls, by means of above-named cranks, the valve rods outwards so that the rollers are pulled away from the steering cams. Then, when the cams are entirely free from the rollers, the horizontal cam shaft is automatically shifted lengthwise by means of guide rollers with a guide curve on the operating shaft, so that the set of steering cams, corresponding to the movement desired, comes into position, and then, finally, the rods with the rollers are again pulled in on the steering cams. It takes about 15secs. for the reversing engine to change the valve motion from forward to back.

The fuel oil pumps are the usual ones, two for each engine, the one being reserve for the other. Under normal conditions both pumps are working, but in case of accident one of them is sufficient to run the engines at full speed. The quantity of oil—and thereby the number of revolutions of the engine—is changed by regulating the suction valves on the fuel oil pump, as these are kept open for a shorter or longer time by the compression stroke according to the position of the lever arms of the valves. These lever arms are regulated by means of an axle which is turned by an operating lever which has a handle with a small pawl, which engages a sector with very small teeth, so that this handle when engaged in a certain position determines the number of revolutions. The same operating lever engages on the front part of above-named sector a slide valve which is placed in the pipe which leads the operating air from the service tanks to the starting valves. As the handle is moved forward from "stop," said slide valve is first lifted into a position allowing air to pass through the starting valves on to the pistons, and when the engines have obtained sufficient speed to light the oil—by running three or four revolutions by compressed air—the handle is carried further over the tooth-sector whereby the slide valve shuts off the air and puts on oil for the fuel oil valves, and then the handle is placed in accordance with the number of revolutions wanted. The operating lever and the handle for the reversing engine are all that have to be moved by the engineer on watch when changing.

The fuel pumps carry the oil to a common pressure pipe.

* Paper read before the Louisiana Engineering Society, October 14th, 1912, and reproduced from the Journal of the Association of Engineering Societies.

and from this it goes through distributors to the fuel valves of the various cylinders. Regarding this manner of distributing the fuel there has been great doubt expressed by the technical profession whether it is correct or not, as most Diesel motor manufacturers either use one fuel pump for each cylinder or one for each half engine (half number of cylinders) so as to enable them to cut out the half number of cylinders by stopping only one of these pumps, and it has been said that it was impossible to distribute the oil by means of distributors so that the engines would run with regularity at all numbers of revolutions.

From diagrams taken it was shown that the greatest variation of the indicated mean differential pressure inside the individual cylinders was 1·8lbs., corresponding to 13 i.h.p., and under the passage through the Suez Canal the "Selandia" was running between two steamers, so that at times the number of revolutions was only 35 per minute. Notwithstanding this, the engines worked regularly without having to cut out any of the cylinders, as has proved necessary in engines of other makes in order to obtain regularity during small number of revolutions, and it seems, therefore, to be correct to use distributors, as it means simpler construction of fuel pumps and regulating machinery.

The regulator is an "Aspinal," such as is used on steam engines. It works through a lever on a valve, which is placed in the common pressure pipe from the fuel oil pumps, and by pressing the valve down it shuts off the oil supply to the engines. When the number of revolutions passes 150, the regulator acts, and the fuel pumps, which keep working as long as the propeller turns the engine, pump the oil through relief valves placed on the air chambers of the pumps. It must be remembered that the regulator only works when the sea is so rough that the propeller blades come above water, and it has been proved that this manner of operation is very satisfactory. During the first trip of the "Selandia" to Siam the aspinals worked incessantly for 60 hours on account of high seas, and the number of revolutions varied from 90 to 150, as the aspinals open again for the oil when revolutions have fallen below the normal. In calm sea the regulation in speed is obtained by giving the engines more or less fuel oil, and for helping the regulation the main shaft of each engine has a flywheel about 6ft. diam., weighing approximately 5 tons. This flywheel may also be used in turning the engines. By means of a small motor-driven turning engine a worm on its shaft can be placed in contact so that the worm engages teeth on the perimeter of the flywheel.

The fuel oil first used by the "Selandia" was from Roumania, and was a dark and heavy oil with a specific gravity of 0·9328 at 15° C. and viscosity of 1·9 at 80°. Its heat value was 39,000 B.Th.U., and the ratio of hydrogen to carbon was 1·6, consequently it was not a very good oil. Nevertheless, the results obtained were satisfactory, as a repeated determination of the oil consumption showed this to be at full speed 0·332lb. per indicated horse-power per hour, including the consumption of the secondary oil engines. This means a daily consumption of 9·8 tons of oil in 24 hours, and, with a capacity of fuel oil tanks of 1,000 tons, means that the ship can make a round trip from Europe to Siam and back, or 100 days' journey, without having to take in fuel and without the fuel occupying any room except the tanks in the double bottom, which are always used in other ships for ballast, thus giving the entire space used in steamships for coal bunkers over to general cargo space.

The main engines have crossheads working on water-cooled guides, and as pressure lubricating is being used for main engines, as well as for secondary engines, all these are constructed with closed bases, and oil-tight doors, so as to allow inspection of crossheads, cranks and main bearings; and in order to give regularity, the cranks of the two half parts of each engine are set at an angle of 90°.

The lubricating oil is pumped by the lubricating pump through the main bearings, then carried through a boring in the crank arm to the crank itself, and further, through the hollow crank rod and piston rod to the piston, the bottom of which is double. After having cooled the piston it goes through another boring in the piston rod and through a pipe down over the guide planes of the crosshead and to the base frame, from where it is carried to a main lubricating oil tank placed in the double bottom of the ship, where there is one under each engine which holds 2 tons of oil. The total amount of oil circulated is about 20 tons. To the same tanks is led the return oil from the secondary engines, which are lubricated in the same manner. The pistons are lubricated through the automatic Mollerup lubricator, which is driven from the horizontal steering shaft. It will be seen that the work of the engine crew, as regards lubrication, &c., is an absolute minimum.

The lubricating pumps consist of two motor driven double acting 2-cylinder plunger pumps, and each of these is sufficient to furnish the two main engines and the two secondary engines with lubricant, so that the other can always be kept in reserve. They work against a pressure of 15lbs. to 20lbs. The suction pipe is carried to the bottom of the tanks, and after having passed the pump, the oil goes through a filter and a cooler so as to be further cooled before going to the engine. The lubricant used is a cheap, clean mineral oil of viscosity 5 at 50° C. The pressure lubrication allows the use of a cheap mineral oil, as the large quantities pumped through the engine exclude the possibility of too thin an oil film and a consequent warming of bearings and wear.

Directly connected to the shafts of the secondary engines there is a dynamo and a secondary air compressor for each engine. The dynamo is of 226 volts and 710 amperes and serves current to all motors on the ship and to the lighting and the wireless telegraph, but for the lighting system the voltage is cut to 110 volts through a transformer.

The secondary compressors, coupled directly to the secondary engines, compress the air in three stages to 300lbs., and they have a capacity of 14 cub. ft. compressed air each per minute, and consume when working with full open suction valves 150 h.p. each. The compressed air is carried to a cooler and from this to the supply tanks, four of which are hung under the deck, and each having a capacity of 120 cub. ft. From these service tanks the air is carried to the main compressors of the main engines and to the air-driven helping engine for starting and reversing the main engines. From the second-stage chamber of the secondary compressors is a connection to the whistle and the siren, and the pressure here is about 120lbs. At sea only one of the secondary engines is working, as the load on the generator, when no winches are operating, does not exceed 50 e.h.p., and the compressor, under normal conditions, runs with almost closed valves; consequently, one of the secondary engines is ample to pull both the generator and the compressor. The other secondary engine is then always ready for immediate use and can be started in a few minutes if it should be necessary to stop the one that is working.

The four supply tanks already mentioned are so ample in size that the main engines can run about one-half hour by the compressed air in them and yet have full power for manœuvring. A trial at sea showed that when both of the compressors were stopped, the pressure in the supply tanks fell during 16 minutes from 300lbs. to 210lbs., yet, even at 150lbs., the engines are fully capable of manœuvring.

It is to be noted that even in case of accident to both of the secondary engines and the secondary compressors, one cylinder on either of the main engines can, by changing of the exhaust valve and connecting by by-pass to the supply tanks, be used as air compressor, and the engine is then running on seven cylinders and is still capable of developing its full horse-power. As a further assurance, there is a steam-driven compressor which is directly connected to a high pressure single cylinder steam engine, which gets its steam from an oil-fired donkey boiler, generally used for supplying the ship with steam heat. This compressor has four pistons, all driven from one crank shaft, and compresses the air in three stages to 900lbs. It is incorporated in the secondary machinery in order to give the most absolute guaranty that the ship will always be able to manœuvre as far as compressed air supply is concerned. This will probably never be used, but it will be seen that all arrangements have been made to assure safety in operation, especially as "Selandia" and "Christian X." were the first real sea-going motor ships.

The exhaust pipes from the individual cylinders of the main engine are carried to a common exhaust pipe, which is water cooled and hung under the deck. From this pipe

the exhaust passes two mufflers for each engine, and the exhaust from the secondary motors is attached to these mufflers. From the mufflers the exhaust is carried through a pipe up through the mizen mast, which is slotted for the escape of the gases about 50ft. above the deck. The muffling is so perfect that even in the calmest weather no sound can be heard on the deck from the engines, and the combustion is so complete that no smoke or gases can be seen to escape.

The circulating pumps for cooling water are motor-driven centrifugals and directly connected to the motor shaft. At full speed each pump gives at 1,600 revs. 50 to 60 tons of cooling water per hour against a head of about 35lbs. One pump is always sufficient for supplying the necessary cooling water. The cooling water is used for cooling the guide planes of the main engines, the head and cylinder jackets of main and secondary oil engines and in the jackets of the air compressors; also for cooling of pressure bearings, exhaust pipes and lubricating oil.

There are two sanitation pumps and general service pumps, which are motor-driven, single-acting plunger pumps, each with three plungers. They are used for pumping water to the deck, for the bathrooms, and can pump water from the sea or from the ship's holds. One piston in each pump is through a suction pipe connected to the cooling water discharge from the main engines and serves to pump warm water to the bathrooms. The ballast pump is driven by compressed air from the supply tanks. It is a double-acting two-cylinder plunger pump with a capacity of 100 tons per hour. The fuel oil pump is air-driven and is a two-cylinder piston pump and serves to pump the daily consumption of fuel oil from the main tanks in the double bottom of the ship into two service tanks located in the engine room, each of which holds 6 tons of oil. They are furnished with float and dial so that the engineer can see what oil is on hand. The main object, however, with these service tanks is to separate water and impurities from the oil, and any water and impurities can be drained off from the bottom.

The ice machine furnishes refrigeration and ice for the stores, and is driven by an 8 h.p. electric motor. The winches on the deck consist of 12 electric winches, half of them with a capacity of 5 tons and half with 2½ tons on single line. The steering engine is hydraulic-electric, and consists of an electric motor which is running continuously, and which is driving a pump with variable stroke which can be regulated from zero to maximum by the man at the wheel. The pressure liquid from the pumps is distributed to two hydraulic cylinders, the plungers of which act on the rudder quadrant.

The weight of all machinery in "Christian X.," including all secondary machinery and donkey boiler, is about 500 tons, or 332lbs. per indicated horse-power, but in order to be practical for warships the weight per indicated horse-power must be reduced to 100lbs., so that there is still a wide field to work on, but since the first very successful trip of the "Selandia" motor shipbuilding has taken on speed, and during the coming years there will undoubtedly be further developments, and many still better results as regards the use of the Diesel engine as a marine engine.

As to the economy, it should be noted that the Diesel engines, for a ship of same size as "Christian X.," would cost about £4 more per indicated horse power than engines and boilers for steam-driven ship of the same size, or a total of about £10,000. To pay for this we have a 1,000-ton extra cargo space, and figuring that only 500 tons of this is made use of, and figuring three round trips from Europe to Siam every year, we have 3,000 tons at 20s. per ton, or £3,000. The saving in fuel between oil and coal, and the saving in the number of crew on a ship of this size amounts to, per year, £5,000, a total minimum saving per year of £8,000 in profit over and above what would be earned by the steam-driven ship. Therefore, four-fifths of the extra cost of the Diesel engine is earned in the first year, and the balance, £2,000, plus an additional £6,000 profit, is earned in the second year, and after that the annual profit is £8,000. In addition to this the cost of maintenance of the motor machinery is much less than that of steam equipment, and it should be noted that the ship does not need to stop from time to time to take in fuel, and that the loading of the fuel itself, sufficient for a 100-day trip, only takes 8 to 10 hours, with a minimum of work and without the accompanying dirt and dust, such as is the case in loading a vessel with coal.

The development of the Diesel engine for marine use has had a tendency to give the 2-cycle motor preference, for various reasons: The 4-cycle motor requires double the number of cylinders called for by the two-stroke motor in order to get the same horse-power developed, provided size of cylinder is the same; and it is necessary to have larger engine room for the 4-cycle engines in order to take care of the larger machinery. On the other hand, there are many disadvantages attached to the use of the 2-cycle engine—of which I shall only mention such things as the heating of the parts being much greater, and its being, therefore, much more difficult to keep the machinery properly cooled. The 2-cycle engine will also consume more oil, which naturally means increased cost; and a larger supply would have to be carried.

As to the space occupied, the present International Marine Laws are such that the determination of registered tonnage is 32 per cent. of the total volume of the ship, in cases where the machinery space takes at least 13 per cent. of the entire volume. If the machinery space is made less than 13 per cent. of the total volume of the ship, then the registered tonnage is determined by actual measurements, and as the registered tonnage is the deciding factor in determination of port fees, canal fees, &c., it will be seen that the earning capacity of the ship is thus decreased. There may come a day, however, when these regulations for ship measurement will be changed, and when that day comes, the space taken up by the machinery will have to be taken into consideration.

The "Selandia" and "Christian X." have just made their appearance and have stirred the nations to renewed efforts in the way of motor ship construction, and we already see a new motor ship, the "Monte Penedo," built by Sulzer Brothers, and which is equipped with Sulzer-Diesel engines, which are of the 2-cycle type. The general arrangement and auxiliary machinery are practically the same as that of the 4-cycle type, and the builders have succeeded in getting the machinery down to a total weight of 177lbs. per indicated horse-power, and as progress will undoubtedly be made on the same lines, and made rapidly, there is no doubt but that shipbuilders will be able to reduce the weight of the machinery accordingly, and we may soon see the navies of the world equipped with Diesel engines—which at present is absolutely prohibited on account of the heavy weights. Otherwise, the Diesel engine would, of course, be the ideal power for a warship, as it takes up little space, gives hardly any vibration whatever, requires a smaller crew to handle, and produces no smoke, thus eliminating one of the means whereby ships are located by the enemy, and as there are no funnels, it gives the large turret guns almost a complete field for operation.

For the detailed information regarding the machinery and its working capabilities on the "Christian X." I am indebted to Mr. Geo. Erichsen, who was sent as guaranty engineer for the ship's builders on its first trip, as well as to Mr. O. E. Jörgensen, the chief engineer of the Burmeister & Wain establishment in Copenhagen.

Institute of Marine Engineers.—The annual meeting of the Institute of Marine Engineers was held on Friday, March 7th, at the Liverpool Street Hotel, London, E.C., the retiring President, Mr. Summers Hunter, being in the chair. A net increase in the membership of 66 was recorded, bringing the total number on the roll up to 1,350. In regard to the proposed new city premises it was stated that the negotiations for the acquirement of the site on Tower Hill were now completed, the total amount subscribed to the special fund being £6,045. The annual report and balance-sheet were duly adopted. £197 was added to the revenue account during the year, after writing off £194 for depreciation on investments, and paying the expenses in connection with the "Titanic" Engineering Staff Memorial Fund amounting to £61. Mr. Thomas L. Devitt was unanimously elected President for session 1913-14, Mr. James Adamson, Hon. Secretary, and Mr. Alec H. Mather, Hon. Treasurer. Five members of the Council retired by rotation, and the following were elected to fill the vacancies: Messrs. George Adams, Robert Balfour, E. H. Green, J. G. Hawthorn, and J. A. Mannell.

RECENT EXPERIENCES OF BABCOCK & WILCOX BOILERS FOR MARINE PURPOSES.*

BY JAMES H. ROSENTHAL.

THE introduction of the water-tube boiler for vessels of any size originated in France, where the Belleville boiler was installed about 1889 in certain ocean-going vessels of the Messageries Maritime Company running between Marseilles and Australia, and also between Marseilles and Algiers. This boiler had already been tentatively adopted in the French Navy for a few cruisers, and the British Admiralty, after a thorough investigation of it in the French merchant service, eventually decided to install it on a relatively large scale about 1893. Other water-tube boilers were coming into use about this period, among them the Babcock & Wilcox type, which, although previously widely adopted for land purposes, was then being adopted on small cargo vessels and tramp steamers. It is proposed to deal in this paper with the development of this type of boiler.

In the early installations of the Babcock & Wilcox boiler, troubles were encountered, but much valuable experience regarding design and operation was gained from them, and this materially assisted in eradicating defects and leading to the present-day successful use of the boiler in the mercantile marine. The troubles referred to were only to a small extent due to questions of construction, and practically the only real defect in design was the lack of combustion space in the furnace. The troubles mainly arose from salt water leaking into the feed water, through the condensers on some of the ships being unsatisfactory, from the steam production for which the boilers were designed being assumed to be less than was really required, and from lack of suitable attention. Constant improvements in material, especially in the quality of tubes obtainable, and design of details, coupled with improved proportions of furnace and in the heating surface for the work to be done, together with the increased knowledge, resulting in a large measure from the earlier experiences, have been the elements upon which the present-day success has been based. It should here be stated that the researches of the Admiralty have been of inestimable value as contributory to this result.

Some trouble was experienced with the Belleville boiler in the ships of the Navy, and this led, in 1900, to the appointment of a Special Boiler Committee, composed of members of the Admiralty and several of the leading marine engineers of the country, to investigate the various types of water-tube boilers which were then brought forward. The result of the committee's report was that the notion which prevailed in certain quarters at the time, to the effect that only the Scotch boiler was reliable for arduous service, was entirely dismissed, and the conclusion, stated briefly, was that a modified Yarrow boiler with large tubes and the Babcock and Wilcox boiler were pronounced to be quite suitable for use in the future on large vessels of the Royal Navy.

TABLE I.

	"Saxonia"	"Hermes"
Transmission of heat units per square foot of heating surface	5,416	6,900
Pounds of coal per square foot of grate	20·6	20
Temperature of feed water	178°	88°
Pressure of steam	199	227
Percentage of moisture in steam	Not taken	·09
Actual evaporation per pound of coal	11·3	10·25
Equivalent evaporation per pound of coal from and at 212°	12·33	12·17
Thermal efficiency	82·3	81
Actual evaporation per square foot of heating surface	5·14	6·2
Equivalent evaporation per square foot of heating surface from and at 212° Fah.	5·6	7·3
Temperature of funnel gases	396°	481°

The first vessel fitted in the Navy with Babcock & Wilcox boilers was H.M.S. "Sheldrake," which, after extensive trials, was used as an instruction ship for stokers. The vessel has now been broken up. The next vessel fitted with Babcock & Wilcox boilers for trial was H.M.S. "Hermes," in which the original Belleville boilers were replaced by Babcock & Wilcox boilers, and on this vessel trials, interesting from the mercantile marine point of view as well as from the naval point of view, were carried out by the Boiler Committee in comparison with the R.M.S. "Saxonia" of the Cunard Company, a vessel fitted with cylindrical boilers of ample size and with Howden's forced draught. These trials were probably the most complete comparative trials of the kind that were ever carried out, and, although published in the records of the Boiler Committee, it will perhaps be considered of interest to have a summary of the results embodied in this paper. In Table I are given the comparative evaporative efficiencies.

When allowance is made for the fact that Howden's heated air system was used in the "Saxonia," that her trial only extended for 13 hours against the 30 hours of H.M.S. "Hermes," involving, of course, in the latter case more loss through cleaning of fires, and that exhaust steam feed heaters were also fitted in the "Saxonia" but not in the "Hermes," it will be judged that the "Hermes" was really the more efficient.

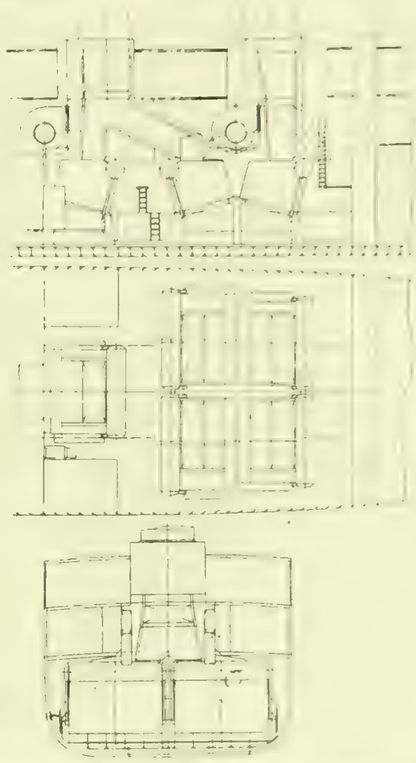


FIG. 1.—ARRANGEMENT OF BABCOCK & WILCOX BOILERS IN CROSS-CHANNEL STEAMER "PRINCESS VICTORIA," OF 7 000 H.P.

Since that time, the Babcock & Wilcox boiler has been very extensively adopted for large naval vessels. In the Royal Navy alone, it is installed to the extent of over a million horse-power, this figure including the boilers of H.M.S. "Tiger," which possesses the largest power ever put into any vessel. For the United States, where the Babcock boiler is virtually the standard boiler for all large ships, it is also employed to about the same amount. The Italian Navy has adopted it in three battle-ships, and it is also fitted in the large super-Dreadnoughts built and building for Argentina, Austria, Brazil, and Turkey. Such a development is in itself an assurance that the boiler has given ample proofs of reliability and efficiency. The extent of the use of this boiler in the mercantile marine up to June, 1912, is shown in Table II.

TABLE II.

	Ships.	No. of Boilers.	I.H.P.
Ocean cargo and passenger service	82	209	183,879
Canadian Lakes cargo service	43	86	80,000
Ocean and river dredgers	34	79	41,186
Harbour and river passenger service	62	116	78,781
Steam tugs	29	43	23,928
Yachts	8	9	3,705
Totals	258	542	411,479

* Paper read before the Institute of Marine Engineers, March 3rd, 1913.

Of the above, some of the principal vessels deserve mention as reflecting more especially the various advantages obtainable from the use of Babcock & Wilcox boilers. For the Channel steamers, where the power is high, and consequently the weight of cylindrical boilers vary considerably in relation to the displacement, the large saving in weight that accrues from their adoption has resulted in a majority of the recent high-speed boats of this type being fitted with these boilers. In this class there are the South-eastern & Chatham Railway Company's mail steamers "Riviera" and "Engadine," of 10,000 h.p. each, built by Messrs. Denny, of Dumbarton; the London & North-western Railway's "Greenore" of 7,500 h.p., and the Stranraer and Larne cross-Channel steamer "Princess Victoria," of 7,000 h.p. (in Fig. 1 is shown the arrangement of boilers in this vessel); and two mail steamers of 11,000 h.p. each, being built by the Société Anonyme John Cockerill for the Belgian State Railways; a vessel of 3,300 h.p. belonging to the United Steamship Company of Copenhagen, for the Harwich-Esbjerg passenger service, the boilers being fitted with superheaters. The saving in fuel for raising steam and the rapidity with which it can be done are also qualities highly prized in these services.

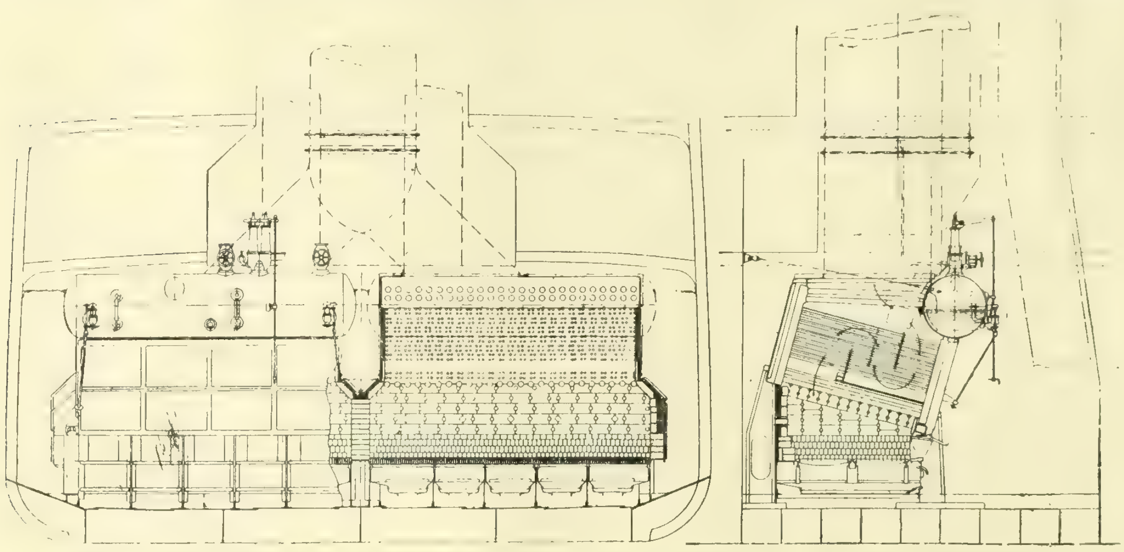


Fig. 2.—Standard Type of Babcock & Wilcox Boiler as Used in the Navy and in the Mercantile Marine.

Among the notable mail and passenger steamers are the "Wahine" of the Union Steamship Company of New Zealand, of 10,000 h.p., now being completed by Messrs. Denny; the s.s. "Creole" of the Southern Pacific Company, of 7,500 h.p.; and three vessels of the Adelaide Steamship Company, of 6,500 h.p. each. These latter bring the number of Babcock boilered vessels in this company up to seven, the first having been in service since 1905. These vessels use inferior Australian coal, for which the large grate and combustion chamber of Babcock boilers is found to be of great advantage. The "Warilda" and "Wandilla" both made non-stop voyages from Glasgow to Sydney last year; the sister ship "Willochra" is now on the voyage out. The other vessels given in the above list include several types of ships—from Thames tug boats to Japanese dredgers; from large steam yachts to American Lake ore steamers, or Egyptian river steamers to ocean-going cargo and passenger vessels.

Experience has shown that the essentials that require consideration to ensure the successful use of water-tube boilers in the merchant service are, in addition to reasonably good management: (1) Well constructed and tight condensers. (2) The use of as little oil as possible in the engine cylinders and proper means of filtering the feed water. (3) Evaporators of adequate size, or other means of ensuring fresh water for feeding the boilers. (4) Regular examination of the water in the boilers, preferably by means of the chemical testing apparatus exhibited; and (5) A careful and interested engineer. These conditions are regularly attained at the present time in all well engineered vessels, and in those cases in which they are not, it is safe to say that considerable improvement would be effected if they were observed.

Fig. 2 illustrates the standard type of boiler as now used in the navy and in the mercantile marine. As will be observed, the boiler consists of the steam and water drum, the sections of tubes, and the mud drum, which are all interconnected by expanded tubes. Opposite each large tube in the bottom row, at both ends, and opposite each end of each group of four smaller tubes an internal handhole fitting, or lid, is provided; these fittings have milled joints and a thin gasket is used. There are no screwed joints in the boiler, tubes and headers are seamless, and all parts are of forged steel of the best quality. The sectionalisation of the tube nest provides for ample elasticity, so that strains of expansion and contraction resulting from quick lighting up or forcing are not detrimental. The furnace arrangement, providing ample space, is well adapted for any fuel, notably also for oil firing alone or in conjunction with coal. A large number of naval vessels are fitted for the use of coal and oil simultaneously, and in some of them the furnaces are fitted for oil only. A design with furnace suitable for coal fuel on the outward voyage, capable of being rapidly converted into a furnace suitable for burning oil on the return voyage, has also been arranged for the special needs of large oil-tank steamers. All boilers are encased by a sectionalised steel casing lined with a non-conducting and refractory material in respect of which it may be said that years of experience have proved its excellent qualities and durability. The furnace is lined with ordinary firebricks, or where the necessity exists for saving weight to the utmost extent, an arrangement of bolted-up fire tiles is provided.

By the kindness of the South-eastern & Chatham Railway Company, a comparison of the economy of the cross-Channel steamers "Riviera" and "Engadine" fitted with Babcock and Wilcock boilers and the "Victoria" fitted with cylindrical boilers is given. The "Riviera" and "Engadine" are slightly larger than the "Victoria," but the vessels are otherwise sister ships. Table III. shows that, taking all points into consideration, the "Riviera" and "Engadine" give a higher economy than the "Victoria."

Table III.

	No. of double trips.	Speed.	Coal per trip.
"Victoria," cylindrical boilers	79	21·272	24·59 tons
"Riviera," Babcock & Wilcox boilers	111	21·868	24·58 ,,
"Engadine," Babcock & Wilcox boilers	94	22·367	24·77 ,,

It is also found that on the Stranraer and Larne Service there is economy in fuel in favour of the "Princess Victoria" over the "Princess Maud," a sister ship of the same power, but fitted with cylindrical boilers. Another notable instance of the superior economy of the water-tube boiler is found in the case of the s.s. "Creole," of the Southern Pacific Railway Company, fitted with Babcock & Wilcox boilers, as compared with her sister vessels, the "Momus" and "Antilles," fitted with cylindrical boilers. These vessels are engaged on the passenger service between New York and New Orleans, a run of about five days, and the average consumption over a recent series of voyages was as follows:—

	"Creole."	"Momus."	"Antilles."
Tons per round voyage ...	1,149 ...	1,412 ...	1,336

The vessels are 410ft. long by 53ft. beam, and are of about 8,000 tons displacement. It will be noted that these results do not refer to the often quoted measurement of "Coal per indicated horse-power." Experience shows that this figure is often misleading, due largely to its being based on a totally inaccurate idea of what the average horse-power at sea really is. Figures as low as 1·1lbs. or 1·2lbs. of coal per indicated

horse-power are sometimes quoted as being obtained in daily service on long distance runs. That such results are hardly possible, or, if so, only in most exceptional cases, can easily be proved. In Fig. 3 is shown the number of pounds of water that a pound of coal of given calorific value will evaporate from and at 212° with a given boiler efficiency. Even taking coal of as high a value as 14,500 B.Th.U. and a boiler efficiency of 80 per cent., it is only possible to obtain 12lbs. of water per pound of such fuel from and at 212° Fah., or 11·2lbs. at the actual working conditions of 200lbs. steam pressure and 200° feed. The figure of 1·1lbs. of coal per indicated horse-power corresponds to a water consumption of 12·3lbs. per indicated horse-power, which very few, if any, triple-expansion engines can attain, even in association with low-pressure turbines and very high vacua. The average quadruple engine requires about 13·5lbs. to 14·0lbs. actual per indicated horse-power, thus requiring an average of about 1·23lbs. of coal per indicated horse-power for the main engines only.

Auxiliary machinery accounts for 15 per cent. of the steam produced in a ship like the "Lusitania" and over 5 per cent. even in a tramp steamer; a fair average of 10 per cent. brings the total steam for all purposes per indicated horse-power of main engines to 15·1lbs., or equal to about 1·37lbs. of coal per indicated horse-power per hour as a minimum, even with abnormally high thermal efficiencies for both engines and boilers, with 200lbs. steam pressure, and feed water heated to 200°. It should be realised that a good average boiler of 70 per cent. efficiency fired with ordinary coal of say 13,400 B.Th.U.'s per pound will only evaporate 9·7lbs. from and at 212°. The feed temperature may only be 150°, bringing the actual evaporation at 200lbs. pressure per pound of coal to 8·67lbs. of water. It is a good triple-expansion engine that requires less than 15·5lbs. per indicated horse-power for all purposes, and under these circumstances this entails a consumption of 1·78lbs. of coal per indicated horse-power. It has been thought necessary to emphasize this, as boiler efficiency in terms of coal per indicated horse-power is often quoted without definition of the engine efficiency. A very low figure for pounds of coal per indicated horse-power frequently means that the indicated horse-power has been exaggerated, and this can generally be proved by the diagram Fig. 3.

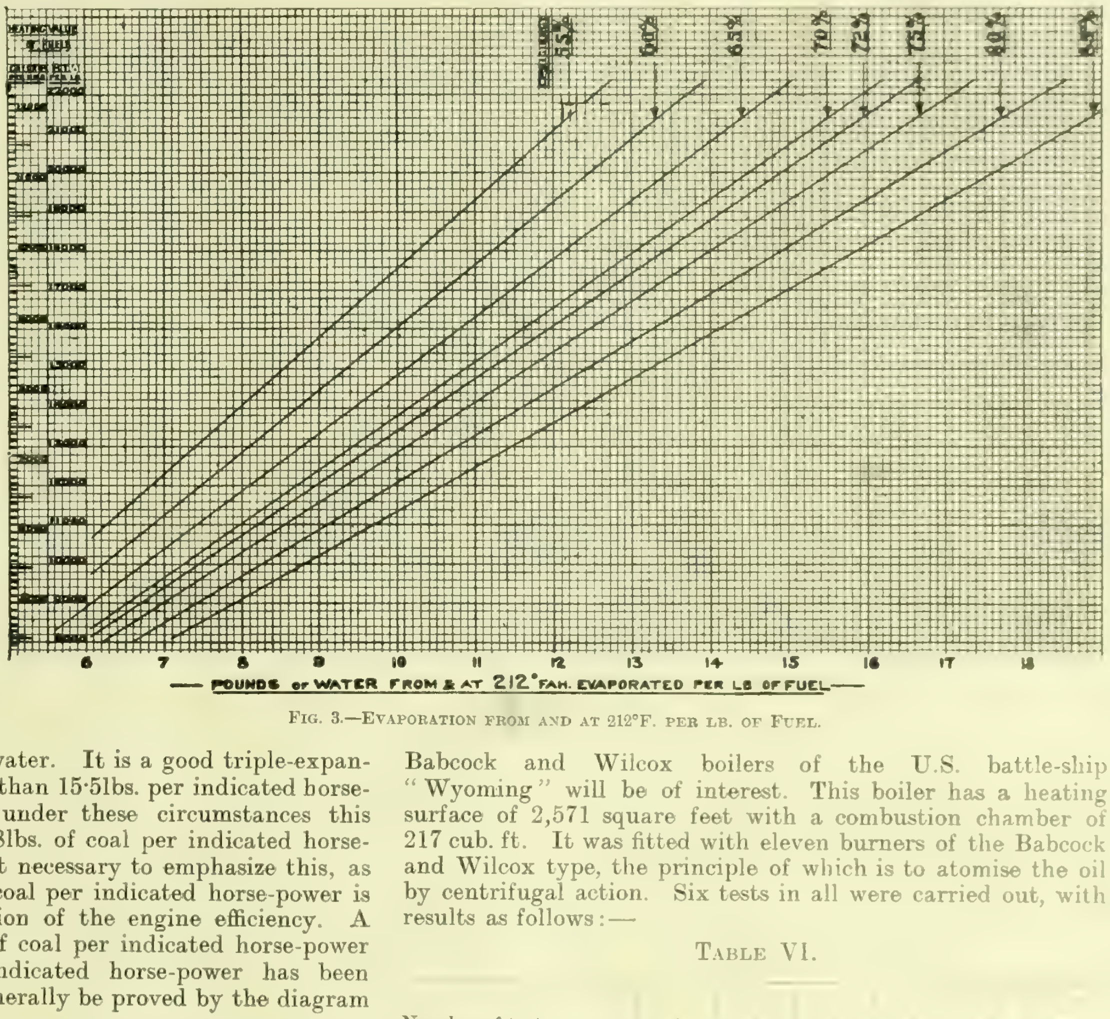


FIG. 3.—EVAPORATION FROM AND AT 212°F. PER LB. OF FUEL.

As far as recent experience is concerned, evaporative trials are rarely carried out on board ship in the mercantile marine, but in the British Navy on the official steam trials the water consumption per shaft horse-power is ascertained in a large number of cases, and the results show that the thermal efficiency of the boilers is about 75 per cent. to 80 per cent. In the case of H.M.S. "Dreadnought" the results of the trials were published, and the main figures are given in Table IV.

TABLE IV.—*Trials H.M.S. "Dreadnought."*

Trial	15 hours $\frac{1}{5}$ full power.	30 hours $\frac{7}{10}$ full power.	8 hours full power.	
Steam pressure, lbs.	220	232	241	
Air pressure	·5″	0·9″	1·2″	
Shaft horse-power	5,087	16,930	24,712	
Coal per S.H.P.	2·42	1·7	1·51	
Water actually evaporated per pound of coal	10·28	10·01	10·03	
Water per horse-power per hour:—				
Main engines	25·1	17·01	14·41	15·56
Auxiliary engines			1·15	

The efficiencies as determined by the Boiler Committee after some very careful and thorough experiments show comparisons between the thermal efficiencies of the Babcock and Wilcox and cylindrical boilers then tested, and are given in Table V.

TABLE V.

Vessel.	Boiler.	Lbs. of coal per sq. ft. of grate.				
		14	18	20	25	29
H.M.S. "Hermes"	B. & W.			81	77·8	
H.M.S. "Minerva"	Cylindrical	69·7			—	68·4
R.M.S. "Saxonia"	Cylindrical			82·3		

In view of the fact that oil burning is at the present time so much to the front, a synopsis of evaporative tests carried out by a Board of United States Naval officers on one of the Babcock and Wilcox boilers of the U.S. battle-ship "Wyoming" will be of interest. This boiler has a heating surface of 2,571 square feet with a combustion chamber of 217 cub. ft. It was fitted with eleven burners of the Babcock and Wilcox type, the principle of which is to atomise the oil by centrifugal action. Six tests in all were carried out, with results as follows:—

TABLE VI.

Number of test	1	2	3	4	5	6
Duration	4	3	3	3	3	2
Kind of oil used			Texas	Crude	Oil	
Number of burners used	3	4	8	8	8	11
Steam pressure, lbs.	212	210·7	210·4	214·8	214·8	209·9
Oil pressure, lbs.	131·3	175·6	188·8	153·2	171·8	191·1
Air pressure in inches	·72	1·6	2·1	2·58	2·79	1·83
Temperature of oil, °F.	210·1	184·0	183·4	199·0	195·7	175·3
Temperature of feed water, °Fah.	211·2	201·0	160·9	185·6	182·8	168·6
Temperature of funnel gases, °Fah	417	533	666	702	630	771
Oil used per hour, lbs.	666	1,202	1,704	1,922	1,947	2,972
Water evaporated per hour from and at 212°, lbs.	10,569	18,895	24,494	27,149	30,064	40,712
Equivalent evaporation per sq. ft. H.S. from and at 212°, lbs.	4·11	7·35	9·53	10·56	11·69	15·83
Equivalent evaporation per lb. of oil from and at 212°, lbs.	15·86	15·72	14·37	14·12	15·44	13·70

In conclusion, the question will be asked, "What are the advantages obtainable with the Babcock & Wilcox boiler over

the well tried cylindrical type, and why is it not more rapidly displacing the latter?" The advantages may be summarised as follows: (1) It is somewhat more efficient in fuel, and much less fuel is required for lighting up. (2) Steam can be raised quickly. (3) It is not subject to detrimental strains due to forcing or to being rapidly lighted up. (4) It is safe from any devastating explosion. (5) Any repairs which might be required could be rapidly carried out by the ship's staff. (6) It is more suitable for the higher pressures and more readily adaptable to oil firing and superheating. (7) In the same ship's space much more grate surface can be obtained, avoiding the necessity for high forced draught. (8) It effects a large saving in weight; and (9) In large installations considerable space is saved.

tions to its adoption, *i.e.* that of inability to comply with the same survey conditions, no longer holds good. On the other hand, the conditions under which the boiler can be successfully adopted were never so favourable as they are at the present time. In the first place, the introduction of the steam turbine for many classes of vessel has eliminated the risk of oil finding its way into the boiler water viâ the engine cylinders. Great improvements in the design of auxiliary machinery and feed-water filters have taken place. The introduction of improved designs of condenser has materially lessened the troubles due to salt-water leakage, while modern evaporators of high capacity and low weight are now more readily obtainable. The immense improvement in tube making during the last few years has resulted in greatly increased

TABLE VII.—*Showing Comparative Sizes, Weighis, and Spaces of Cylindrical and Babcock & Wilcox Boilers.*

Type of Ship.	Intermediate Passenger Steamer.		Large Cargo Liner.		Large Combined Passenger and Cargo Liner.		Large Intermediate Atlantic Liner.			Large Fast Atlantic Liner.			Large Fast Atlantic Liner.	
Estimated steam production per hour from feed at 150 Fah., 200lbs.	75,000		112,500		140,000		240,000			750,000			1,000,000	
Estimated steam per I.H.P. per hour for all purposes	15		15		14·0		15			15			14·3	
Equivalent horse-power	5,000		7,500		10,000		16,000			50,000			70,000	
Type of boiler	Cylindrical	Babcock	Cylindrical	Babcock	Cylindrical	Babcock	Cylindrical	Babcock		Cylindrical	Babcock	Babcock alternative	Cylindrical	Babcock
Heating surface, sq. ft.	13,300	16,370	21,750	25,850	26,500	32,515	52,150	57,810	66,200	146,000	188,510	164,650	158,350	221,544
Grate area, sq. ft.	335	450	530	650	700	900	1,260	1,600	1,800	4,000	5,170	4,480	4,050	5,474
Approx. weight of boilers and water, and all mountings and fittings, but no funnels or uptakes, or stokehold accessories, tons	420	195	535	282	780	380	1,320	672	825	4,200	2,360	2,035	4,750	2,615
Draught	Howden	Assisted	Assisted	Assisted	Howden	Assisted	Natural	Natural	Natural	Assisted	Assisted	Assisted	Howden	Assisted
Floor space occupied by boiler-rooms, sq. ft.	1,850	1,585	3,420	2,280	3,835	3,068	7,275	5,700	5,920	20,268	20,268	13,460	18,235	16,115
Fore and aft length of boiler-rooms and transverse bunkers	56′ 0″	44′ 0″	72′ 0″	51′ 0″	77′ 0″	71′ 0″	127′ 6″	106′ 6″	117′ 6″	321′ 0″	321′ 0″	252′ 0″	-	—
Increase of H.S., per cent.	-	23·0		19·0		22·5	-	10·81	26·9		29·0	12·8	- -	39·9
Increase of G.S., per cent.		34·3		22·5		28·5	-	27·0	42·8		29·15	12·0	—	35·3
Saving in weight, tons		225		303		400	-	648	495		1,840	2,165		2,135
Saving in floor space, per cent.		14·33		Entire feed stoke-hold.		2 0 per cent. and longitudinal bulkheads now fitted 6′ 6″ from sides.		Entire forward stoke-hold.	10′ 0″ saving in length and longitudinal bulkheads 7′ 0″ in from side adopted.		Existing spaces used to install much larger boilers.	Longitudinal bulkheads installed.	—	11·63
Saving in fore and aft length		12′ 0″		About 27′ 0″	- -	6′ 0″		21′ 0″	·	—		69′ 0″	--	53′ 0″

The Babcock & Wilcox boiler is rectangular in shape, and as the spaces between the bulkheads available for boilers are usually rectangular, it is obvious that this shape more efficiently covers the floor space available for grate area, whilst the shape lends itself to the installation of considerably more heating surface than is possible in the same over-all dimensions with a cylindrical boiler. Table VII. gives approximately the relative heating and grate surfaces for both types of boiler for several classes of ship, and indicates the gain in weight and space occupied that would be due to the use of Babcock boilers

It is not necessary to elaborate the advantages to the ship, as a whole, that are derived from these gains. Now that the Board of Trade grants the Babcock boiler the same certificate as it does to the cylindrical boiler, one of the leading objec-

reliability. Besides all these mechanical reasons, more accurate estimates of boiler power required and the consequent dimensions necessary are now made. All these contributory causes are tending to facilitate the wider adoption of the water-tube boiler. Even if the marine engineer is not very conservative, the shipowners are, and the natural self-interest of the ship-builder to utilise his expensive plant for making cylindrical boilers has been a retarding influence. It may be stated, however, that there are signs that these deterrents are yielding to the progressive spirit of some of our leading shipbuilders. The cost of Babcock & Wilcox boilers is perhaps slightly more than that of cylindrical boilers of equal power, but the difference is insignificant in comparison with the value of the ship and the greater earning capacity, owing to the saving in weight and space occupied.

IMPROVEMENTS IN GAS TURBINES.

IN gas turbines in which a combustible gaseous mixture is burnt in separate explosions and then flows with expansion through an outlet aperture into the actual turbine, the outlets through which the gaseous products of combustion flow from the combustion chamber to the vanes of the turbine wheel have hitherto been formed as nozzles, that is to say, with convergent-divergent walls entirely following the steam turbine construction. A different formation of these outlets has recently been patented by Hans Holzwarth, of B. 7. 18, Mannheim, Germany, and Erhard Junghans, in which plano-parallel walls are provided. Fig. 1 shows the outlet passages formed with convergent-divergent walls, and Fig. 2 shows the outlet passages having plano-parallel walls. *e* indicates the outlet from an explosion chamber, and *f* the guide passages leading from this outlet to the blades of the turbine.

Theoretical and experimental investigations have shown

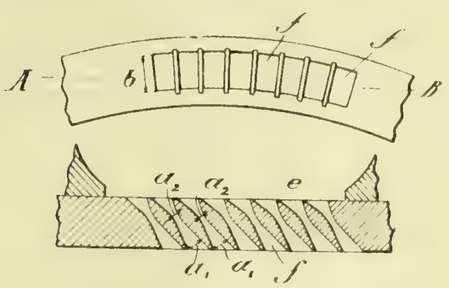


FIG. 1.

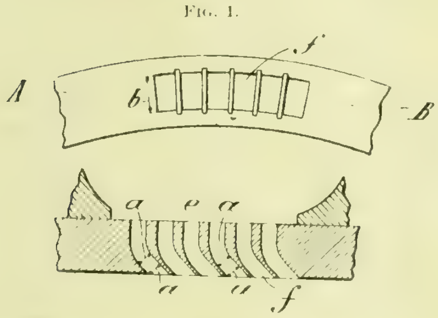


FIG. 2.
IMPROVEMENTS IN GAS TURBINES.

that such outlets with plano-parallel walls are preferable when the highest momentary energy drop causing the outflow is smaller than the value $\frac{1200^2}{2g}$ metre-kilograms per kilogram of the working fluid, g indicating the acceleration due to gravity (9·81 metres per second per second). In this case the momentary maximum speed of the escaping hot gas is, in fact, less than 1,200m. per second. It is therefore no more than about 50 per cent. above the velocity of sound in the gas in question, as the momentary maximum velocity of sound in the hot combustion gases employed in gas turbines amounts to about 780 metres per second. The speed of flow of approximately 1,200 metres per second, which is thus preferable and admissible with guide devices having plano-parallel walls, also enables the energy of the gaseous mixture exploded to be utilised with the best effect. In steam turbines this speed of flow would lie considerably above the velocity of sound in steam (440 metres per second) and does not allow of plano-parallel outlets being employed. Outlets with plano-parallel walls are, the inventors state, of particular importance for gas turbines with periodic explosions, because in these gas turbines the drop of heat to be utilised varies greatly, whilst a convergent-divergent nozzle only gives a good degree of efficiency with a very closely limited heat drop, but the plano-parallel outlet aperture affords a good and but little varying degree of efficiency even if the heat drop varies within wide limits.

The cross-sectional area of the outlet aperture with plano-parallel walls must, other circumstances being equal, be about equal to the cross-sectional area of a nozzle with convergent-divergent walls at the actual outlet, and about equal to double the cross-sectional area of such a nozzle at its narrowest place. It will therefore have a value greater than $\frac{1}{100}$ of the volume of its combustion chamber divided by the diameter of a sphere equal in volume to the combustion chamber.

The point above discussed will be made more clear by reference to the illustrations. The total cross-sectional area of the outlet from a combustion chamber in the case illustrated in Fig. 2, that is where the guide passages are plano-parallel, is represented by the expression $\sum a . b$, and this must be equal to the total cross-sectional area of the outlet formed as shown in Fig. 1 with convergent-divergent walls, this cross-sectional area being measured at the actual outlet point and being represented by the expression $\sum a_1 . b$, or approximately equal to double the total cross-sectional area of the narrowest part of the convergent-divergent passage represented by the expression $2 \sum a_2 . b$.

LIQUID FUEL FOR SHIP PROPULSION.*

BY C. ZULVER.

(Concluded from page 251.)

IT is scarcely necessary to say that the results obtained from the "Vulcanus," and the experience furnished by the vessel since the engines were designed some four years ago have been invaluable elements in the improvements which have been introduced into the internal-combustion engine, and the writer has collected much valuable information that will be utilised in connection with our new motor ships—four of 5,000 tons each—now in course of construction. The vessels will be fitted with twin-screw 4-cycle Werkspoor Diesel engines of a combined horse-power of 1,700 brake, which are expected to give a speed of 10½ knots. The writer is aware that at present the general tendency is in favour of the 2-stroke cycle principle, and undeniably the advantages of increased power for like cylinder dimensions and in engine weight are very attractive. In the case of a warship, as a matter of fact, the question of maximum power for mimimum engine weight is all-important; but, again, one has to consider the point of reliability for continuous work and under adverse and varying conditions of weather at sea. In this latter respect the 4-cycle Diesel engine has, in the writer's view, proved the superiority; at any rate, vessels both large and small are now running with this type of engine and have shown themselves reliable over long distances. After two years a position of something like finality was reached, and subsequent satisfactory performances of vessels thus propelled seemingly assured. Here we observe the outcome of some 12 years of experiment and research, and to sacrifice in some measure this valuable experience of the 4-cycle motor's utility at sea in order to build 2-cycle engines does not, from the commercial standpoint, appear by any means to be a wise course at present.

Progress, however, must and will be made, and it would be idle to pretend that the 4-cycle description represents the ultimate perfection of the Diesel marine motor. As a matter of fact, seeing that so many eminent engineers, both at home and abroad, are taking up the 2-cycle engine and show a preference for it, one may assume that in course of time the two-cycle will prove itself to be just as good and perhaps better than the four-cycle for certain purposes. But

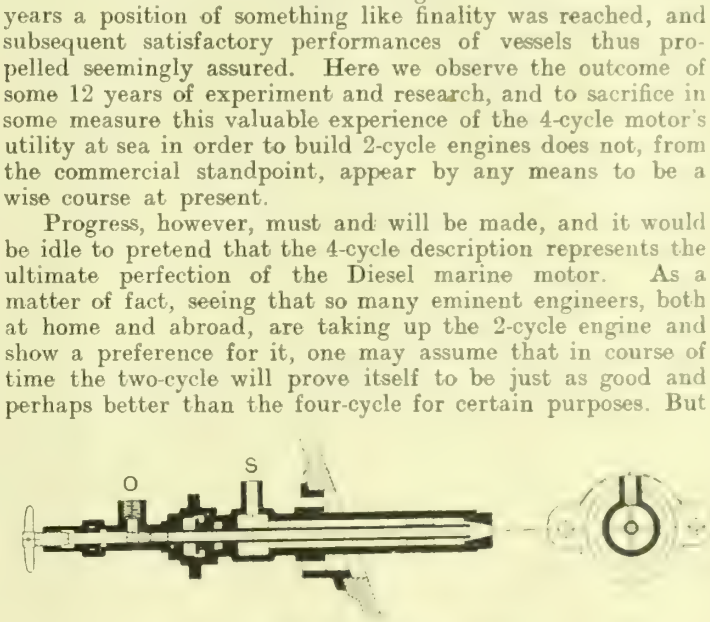


FIG. 2.—STEAM LIQUID FUEL BURNER.
O, oil inlet; S, steam inlet.

at the present stage of advancement, the writer is quite satisfied that the company to whom his services are given are well advised to adopt the 4-cycle engine. He is thoroughly convinced that the 4-cycle Werkspoor Diesel engines now running and in course of construction bear satisfactory comparison, as regards weight per horse-power, fuel consumption and price, with most, and perhaps all, of the large 2-cycle marine engines for merchant vessels now being built, and he suspects that in point of reliability they will be

* Paper read before the Institute of Marine Engineers.

superior, because of the builders' much longer experience of the construction of this type of engine. He ventures to think that experience is a quite invaluable factor in the making of Diesel engines, and that however good a new principle or departure may seem to be, defects must of necessity develop. Every engineer who has been in close touch with the manufacture and running of these engines knows how difficult it is to get metal and castings which will satisfactorily and continuously withstand the severe conditions and high temperature of the Diesel engine, and even with the 4-cycle engine many have been the cracked pistons and cracked cylinder heads which had to be condemned. With the 2-cycle engine the heat generated on piston and cylinder heads is double that in the four-cycle, and it is highly probable that there may be a source of trouble with the 2-cycle engine on a long run from this source.

The principal drawbacks associated with the 2-cycle engine are, in the writer's view: (1) Double heat generation of pistons; (2) ports in bottom of cylinders making the permanent tightness of a liner doubtful; (3) complications with scavenging pump; (4) higher fuel consumption, probably 15 to 20 per cent.; (5) no relief to moving parts, thus necessitating larger bearing surface; (6) long trunk piston necessary to close ports in bottom of cylinder; this long piston design does not make a desirable mechanical arrangement; slight wear and tear of guide may result in "seizing" of piston.

There is one more point to which it may be desirable to draw attention before changing the subject of the comparison of different types of Diesel engines, and that is, that experience has shown the advisability of occasionally examining and cleaning the pistons, particularly when heavy asphaltic or residual oils are used.

With the 4-cycle engine a low piston is used, the height being about 12in., compared with some 3ft. or 4ft., as depends the stroke of the 2-cycle engine. The improved Werkspoor design permits of the piston being completely exposed for examination and cleaned in from 10 to 15 minutes. The piston is removed from the bottom, there being no loose cylinder covers and the cylinder head one with the liner. This device has proved a great success and advantage, and in the case of the "Juno" all pistons were examined and cleaned in a few hours without disturbing any pipes, valves or cams. Turning to the 2-cycle engine, to the best of the writer's knowledge, it entails a great amount of work and expenditure of time to do this. There is the slacking back of heavy nuts which hold the cover and the removal of the entire cover with its fuel and cooling pipe connections, valve levers, &c., in order to get at the piston, which has to be loosed from the rod and lifted up in the usual way. Because of the restricted space on the gratings, only one, or at the most two, covers and pistons can be dealt with at a time, and it can readily be imagined what this means in time and labour on a twin-screw vessel with two six-cylinder engines.

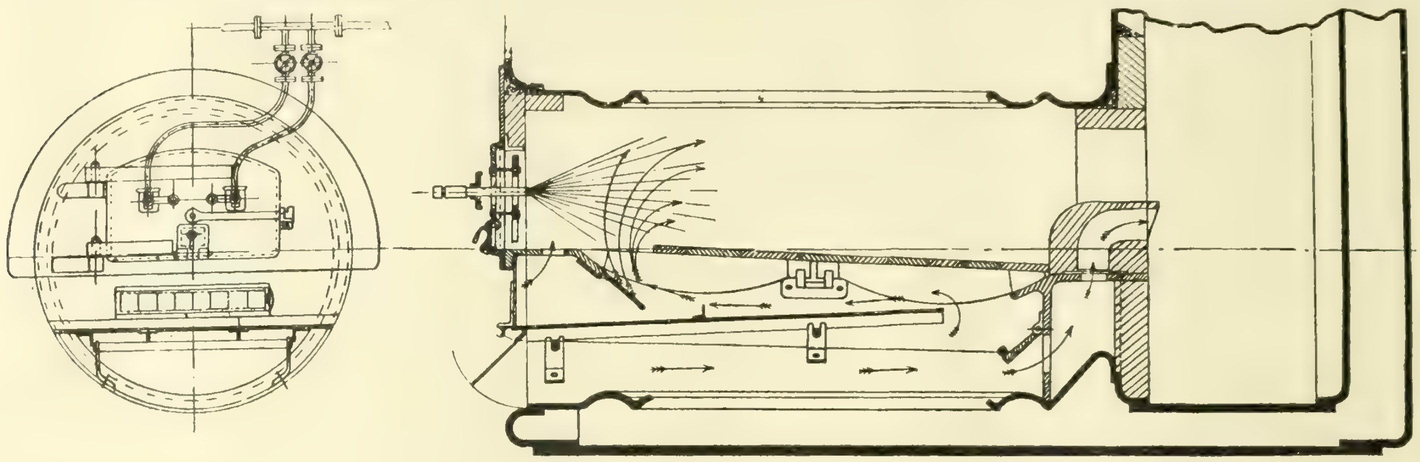
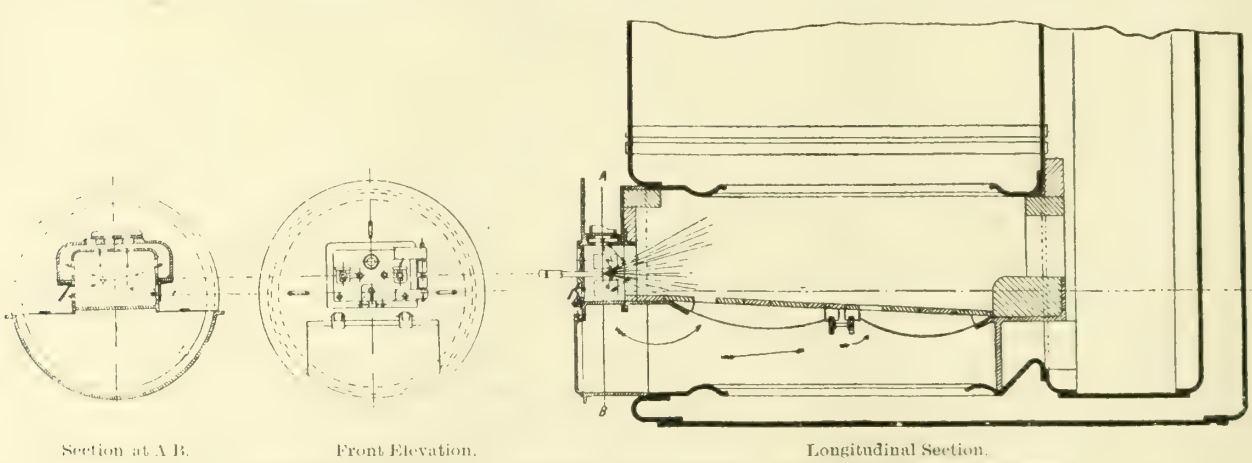


FIG. 3.—FURNACE ARRANGEMENT FOR BURNING LIQUID FUEL AND COAL.

The writer being himself a marine engineer of many years' experience at sea, appreciates these facts in their full practical significance, and after very careful thought he has come to the conclusion that for merchant vessels the 4-cycle engine, apart from its supremacy by reason of its more economical fuel consumption, will continue to show such results in general economy and reliability as will long make it a very serious rival of the 2-cycle engine, to say the least of it.

The merits and demerits of the various oil-burning systems now claim attention, but before entering on this branch of the subject the writer thinks it well to accentuate the more salient advantages of oil fuel over coal. (1) The calorific heat value of liquid fuel is about 19,500 B.T.U., as compared with good Welsh coal having 14,500 B.T.U., or about four of liquid fuel to three of coal. This means that the quantity of heat contained in equal weights of liquid fuel and coal is 25 per cent. greater in the case of the liquid fuel. According to the description of the coal, there is a variation in favour of liquid fuel up to 35 per cent. Hence it arises that the consumption of liquid fuel contra coal in raising steam is less in the ratio of the above percentages, liquid fuel thus increasing the net deadweight of the vessel for cargo and reducing the required bunker space. (2) Liquid fuel can be sorted in spaces where coal cannot be carried, viz., double bottom, peak tank, cofferdams, &c. (3) Bunkering can be done quickly and while steamer is loading, discharging, or receiving passengers on board. The importance of this fact



Section at A B. Front Elevation. Longitudinal Section.

FIG. 4. IMPROVEMENTS TO FURNACE FRONT FOR BURNING LIQUID FUEL UNDER FORCED DRAUGHT.

in the case of a large passenger liner will be readily appreciated. (4) The trimming indispensable with coal is unnecessary for oil fuel, the latter being pumped direct from compartment to furnace; hence a saving of manual labour and reduction in number of firemen. (5) No cleaning of fires is needful, and with no ashes to deal with the stokehold remains clean, with resultant reduced cost of upkeep of stokehold and boilers. Again, no cleaning of fires being necessary no cold air can get access to the furnaces, so that leakage and other damage of boilers on account of unequal expansion and contraction is avoided. (6) Steam production can be readily adjusted, according to requirements, and the stand-by loss over banked fires largely avoided. (7) Great regularity in steam production, the maintenance of better speed through dispensing with the cleaning of fires, and enhanced efficiency of boilers owing to absence of smoke and soot, whence is derived a much cleaner heating surface than with coal burning. (8) Full steam can be maintained throughout long runs by purely mechanical means, and the

First, burning oil fuel by means of steam. In principle the method consists of heating and atomising the oil fuel by means of steam from the boiler. The installation in its simplest form is made up of a small steam pump conveying oil from bunker to daily supply tank, placed in some convenient position high up in stokehold or on casing. The oil, after passing a filter gravitates to the burner, of which a good and simple type is shown in Fig. 2. The daily supply tank is usually fitted with a steam coil to facilitate the separation and settling of any water which may be mixed with the oil. On looking at the sketch of the steam burner it will be noted that the oil in passing through the internal tube is heated by the surrounding steam, while the oil fuel is thoroughly atomised by meeting and mixing with the steam at the removable nozzle. The burner is lighted by means of a few pieces of wood being ignited in some waste soaked in kerosene. Once started the proper amount of steam in fuel can be adjusted to a nicety, and a bright, smokeless, but not entirely noiseless flame produced. There is, however, one

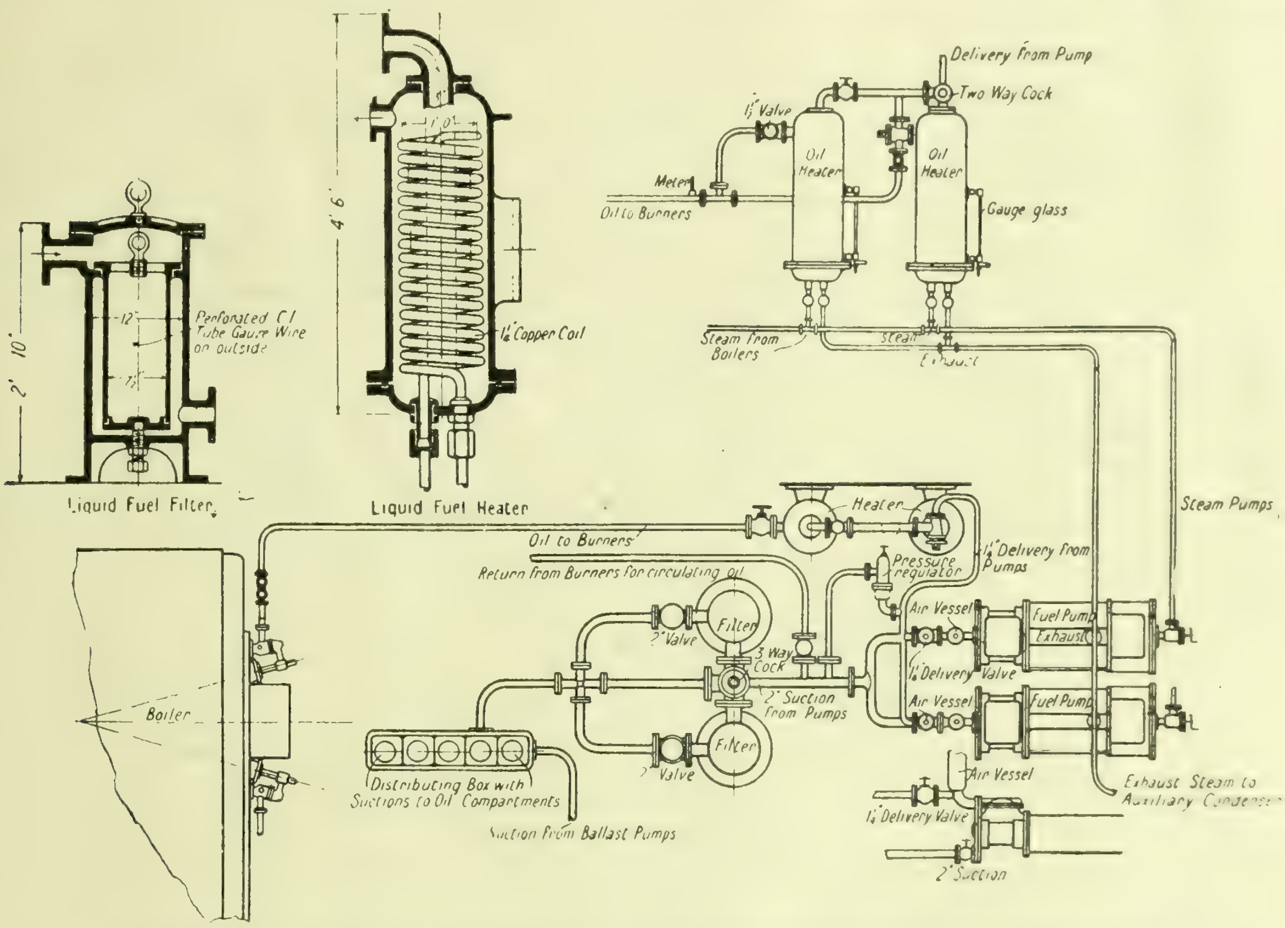


FIG. 5.—COMBINATION OF LIQUID FUEL BURNING ARRANGEMENTS, SHOWING PUMPING, FILTERING AND HEATING PLANT.

oil-fired ship is entirely independent of skilled firemen, an important consideration with mail steamers. (9) Wear and tear of boiler is less, as they are kept at a uniform temperature with closed fire doors and fixed steam production. (10) Greater efficiency of the boilers from more perfect combustion, with less air, less products of combustion, less heat lost in funnel, and with a hotter furnace.

Oil fuel, as is well known, may be consumed with practically any type of steam boiler, and the following are the methods chiefly in favour: (1) Mixing the oil with a steam jet and heating and atomising it by means of a steam burner of simple design, through which the oil is forced under low pressure by means of a pump or of gravitation from a settling tank. (2) Using compressed air burners, which act on the same principle as steam burners, but which involve air compressors, thus rendering the installation somewhat complicated and expensive and reducing reliability. (3) The direct-pressure system without the use of steam or compressed air to atomise and burn the fuel.

It is proposed to give a short description of each of the foregoing systems, with a few remarks as to which would be found to be the most advantageous under certain conditions.

great drawback to burning liquid fuel with steam, in that the operation entails using a considerable quantity of fresh water, which must either be carried, thus reducing the ship's deadweight carrying capacity, or procured from sea water by means of evaporation, with consequent higher consumption of fuel. It is for this reason that sea-going vessels burning liquid fuel are rarely fitted with an installation of which the use of steam is a feature.

Secondly, the consuming of liquid fuel by means of compressed air. Of this it has already been observed that it complicates the plant by the addition of air compressors, thereby increasing first cost and expense of maintenance to an extent which, in the commercial aspect, greatly militates against its desirability. Nevertheless, the method is extensively adopted on warships, and it must be admitted that smokeless combustion is readily obtained and that the consumption of fuel is economical. The compressed air burners work on the same principle as the steam burners, air pressure varying from 1lb. to 5lbs. The air is heated by passing through a pipe in furnace or through suitable heaters placed in uptake. The admission of air and fuel is regulated by hand wheels, which operate pinions and racks controlling the

fuel and air tubes, so that the apertures are opened and closed as may be necessary.

Thirdly, the direct-pressure system. This system is generally used for commercial purposes and can be utilised under either forced or natural draught. It may here be observed that the forced draught method, as well as the natural draught, is well adapted to burn liquid fuel and to secure smokeless combustion. The same furnace fronts may be used in each case for both oil and coal burning, and conversion to either fuel can be accomplished with facility and speed. Furnace fronts and arrangements for burning liquid fuel under natural and forced draught are shown in Figs. 3, 4, and 5. With the direct-pressure system the fuel is filtered and heated, and at a pressure of 30lbs. to 100lbs. pumped through an atomiser burner which is fitted in furnace front. On ignition the oil burns with a bright flame and so continues so long as a sufficiently high pressure is kept up, and the temperature of the oil varying, in accordance with the flash point, from 150 to 200° is maintained. The burners are set away by means of a torch or a piece of burning wood as soon as the oil has attained the required temperature, which, when lighting up, is brought about by circulating the fuel through the heaters.

Turning to the problem of safety and comparing the risk of burning coal and burning liquid fuel, the writer is convinced that if reasonable care be taken there is no more danger when using liquid fuel than when using coal, and that on considering the carriage and storage of both fuels, it would appear that liquid fuel can be carried with a greater measure of confidence than coal, in view of the liability of the latter to spontaneous combustion. It may further be urged that, unlike coal, liquid fuel does not deteriorate to any degree of loss in its calorific value. The measure of safety with which liquid fuel may be consumed in ships' furnaces is largely dependent on the flash point of the oil. With the facilities for storage and burning now chiefly adopted in vessels using liquid fuel, this should not be less than 150° Fah., unless special precautions have been taken in the shape of separate oil and gas-tight compartments for pump, heater, filter, &c., and even then the writer is of opinion that skilled attendance would be required in order to avoid accidents.

The peculiarly penetrating nature of oil fuels, and especially of light oils, is well known, so that it is extremely difficult, if not impossible, to prevent small quantities of leakage oil from finding their way to stokehold bilge through either joints of fuel system or leaking steams or rivets of bunker. High-flash oil is almost harmless as long as the surrounding temperature keeps well below its flash point. This has invariably been found to be the case, even when the fuel is close to the boilers in stokehold, and for this reason naked lights can be used in the immediate vicinity without fear of accident. But low-flash oil, besides filling the boiler room with obnoxious and inflammable emanations, would readily catch fire from a spark or naked light. A signal advantage possessed by high-flash oil in the matter of safety is that, should, through negligence, a fire break out in the stokehold—because, for instance, of liquid fuel being allowed to leak into bilge and there accumulate—it could readily be extinguished by a spray of cold water, for water would at once lower the temperature of the oil to below its flash point and prevent a continuation of the outburst.

Contrary to the popular belief that water on burning oil makes matters worse, the writer has found that in dealing with burning liquid fuel of high flashpoint there is no better and speedier fire-extinguisher than water, which, on board ship, is always at hand in abundance by keeping the ballast pump ready for the purpose, or in a loaded ship by simply opening the ash cocks. Liquid fuel and water mix easily on account of the specific gravity being nearly equal, 0·95 and 1, while a mixture of liquid fuel and water cannot burn. The best means of preventing accidents in the shape of fire are, of course, cleanliness and a liberal use of the hose in washing floor plates and bilge out occasionally. In thus removing all trace of liquid fuel the risk of fire is likewise removed. With these few remarks the question of safety under liquid fuel burning conditions may be dismissed.

No review of the advantages of liquid fuel burning, however cursory, should fail to refer to the need that must occasionally arise of converting the furnaces of liquid fuel burning steamers to coal. From the commercial aspect, indeed, this is a matter of much importance, and it may here be mentioned that to meet the requirements of vessels which trade to countries where coal is cheap and liquid fuel costly, or coal dear and liquid fuel cheap, as the case may be, and which for this reason find a liquid fuel burning system, inexpensive and speedy in installation, a great desideratum, the writer some years ago, in an effort to meet this want, designed a system which has yielded satisfactory results.

With this method a steamer's boilers can be converted in a few hours from coal to liquid fuel or vice versâ. The expense amounts to a few pounds for a couple of hundred firebricks and the ship's own staff can effect the conversion without any trouble or delay to the steamer. As a matter of fact, coal and liquid fuel could, if so required, be burnt at one and the same time. For cargo and mail ships it would be a great advantage if they could burn at a moment's notice and without expense in conversion, either liquid fuel or coal, as was the more economical under the immediate circumstances. Nearly all large steamers now have double bottoms, of which the capacity ranges from 500 to 1,500 or 2,000 tons. In this liquid fuel could be carried; permanent bunkers need not be altered, but could be allowed to remain always available for the reception of coal.

The reason big steamship companies are not at present adopting liquid fuel burning methods on their vessels undoubtedly revolves about the problem of supply; and at the present stage of the evolution of liquid fuel it must be admitted that ample and continuous supplies could not be relied upon at their steamers' various ports of call. For a steamship management to incur the possibility of delay to a liner in laborious conversion to coal burning because of the depletion of local liquid fuel stocks is naturally a position which they will not contemplate, and the arousing of their active interest in the subject must clearly await the removal of this disability. With the writer's system this one great impediment to their adoption of liquid fuel is conclusively surmounted. As a demonstrable fact a steamer burning liquid fuel could in a few hours be made to burn coal, and the coal loaded into the ship's permanent coal bunkers, the double bottom, as has been remarked, being reserved for liquid fuel. Again, some of the boilers could, if advantageous, be fired partly with liquid fuel and partly with coal, and the conversion could be effected at sea without loss of time or reduction in speed of vessel.

The method under notice is equally adaptable to stationary or locomotive boilers on shore, and has importance in this connection, if only because of recurring coal strikes. The freedom of manufacturers who use steam from this source of possible interruption would be assured by the fact of their preparedness to burn liquid fuel in an emergency, and when the mining industry resumed its normal aspect reversion to coal would be a simple, speedy, and inexpensive matter. Largely for this reason, no doubt, the subject of liquid fuel has of late enjoyed increased favour in this quarter, and signs are not wanting that the introduction of a system which met all possible objections would result in a great impetus to the growing popularity of liquid fuel in our manufacturing centres.

Having submitted this brief review of the advantages of oil fuel over coal for power-producing purposes, one must deal with three questions that would be asked by every business man:—(*a*) What would be the price of this oil fuel? (*b*) At what points could it be obtained? (*c*) Can regular supplies and stocks be relied upon? With regard to the price of oil under existing abnormal conditions of insufficient transport facilities and consequent high freights, it is at present naturally higher than it will be when the fuel has assumed its right commercial position, and varies for each particular port in accordance with its distance from oil-producing centres. The writer is not inclined to go into the prices at which oil fuel can be bought at various European and Far Eastern ports under the now changing conditions. Suffice it to say, that with the enormous increase in the production of oil, we now witness the active opening up of new territories and the building of so many tank steamers that the completion of a boat is almost a daily incident, the price of liquid fuel will soon fall to a level at which shipowners throughout the great ports of the world will be compelled to admit its advantages over coal. And here the fact may be mentioned that of late the price of coal has advanced considerably, while even higher prices are apprehended in future years. Again dwelling, also, on the salient facts that a ton

of oil in a Diesel ship does as much work as 4·5 to 5 tons of coal, that there is a marked saving in personnel and that there is an increased deadweight cargo-carrying capacity, it is clear oil must in some parts of the world entirely supersede coal, as, in truth, it has already done to a certain extent.

It may be interesting to name a few ports where large stocks of fuel oil are kept. They are: London, Rotterdam, Bizerta, Black Sea, Port Said, Suez, Colombo, Madras, Karachi, Bombay, Calcutta, Rangoon, Singapore, Balik Pappan, &c., and all over Eastern Hemisphere, Australia, America, &c., and within a comparatively short period oil fuel will be obtainable on all the principal trade routes of the world. In Borneo and Texas enormous quantities of fuel oil are waiting to be placed on the market as soon as sufficient tank steamers are available.

The writer is well aware that, as a rule, shipowners are of a rather conservative disposition with regard to the adoption of new methods so entirely different from established practice, but when the Diesel engine from its first appearance some 12 years ago as a power producer has so conclusively proved its enormous superiority in fuel economy, as well as in other respects, as compared with the use of steam, also for marine propulsion, there can be no doubt that it would be sound policy on the part of shipowners to avail themselves of its obvious advantages.

As regards the use of fuel oil for steam boilers, the writer is of opinion that there is still an enormous field for its adoption for all classes of vessels, both those in service and in course of construction, and particularly so in conjunction with the turbine for war and passenger ships of high power. For, although high-powered Diesel engines have been recently built and are said to be running satisfactorily on the test bed, developing as much as 2,575 h.p. per cylinder, some time and experience are no doubt yet required to develop engines of this power per cylinder into absolutely reliable prime movers for present-day Atlantic greyhounds or powerful war vessels.

DEVICE FOR TURNING AND SCREW-THREADING METAL.

This device, the invention of Mr. H. S. Land, 8, Park View, Old Road, Lee, Kent, is illustrated in end and side elevations respectively in Figs. 1 and 2, while Fig. 3 shows a longitudinal section of the screw-cutting die head. It consists essentially of two elements, namely, a tool box A and a screw-cutting die head B forming a combined turning and screw-cutting tool which is carried by the lathe mandrel. The die head is pivotally mounted upon the tool box head C by means of a pin D, which is also fitted with a spring-urged latch F adapted to lock the die head in either of two positions, namely, with the die head concentric with the tool box as shown in full lines in the drawings, and also with it swung aside upon the pin D clear of the front face of the tool box head as shown in dotted lines. The gauge for determining to what extent the blank is pushed forward through the hollow spindle of the lathe head in order to make a screw or turned bolt of a predetermined length, is mounted upon the tool box head and consists of an arm G which is hinged at H upon the tool box head C so that it can be turned inwards to project radially across the face of the tool box head when used as a gauge or stop, and when not in use, is swung outwards to the position shown more particularly in Figs. 1 and 2.

Mechanism is provided whereby the screw-cutting dies M are advanced into the operative position and automatically released and returned to the inoperative position. The cam disc N by which the screw-cutting dies M are advanced is provided with two teeth or projections R S, one tooth being slightly in advance of the other. When the disc N is rotated by means of its handle until the first tooth R displaces the latch O and engages behind it, the dies M are adjusted for taking a roughing cut, and when the disc N is advanced further until the second tooth S engages behind the latch O, the dies are in position for the finishing cut. The lever P by which the latch O is retracted at the appropriate moment to release the disc N (which is then returned to the normal position by the action of the spring T) has mounted upon its tail end a rod V which is arranged to be adjustable in a longitudinal direction so that it can be moved more or less radially with respect to the centre of the die head, a set screw W being provided for clamping it in the position to which it has been adjusted. Slidably mounted in the end of this rod V is another rod X adjustable in a direction parallel with the axis of the die head and also provided with a suitable clamp, whereby it may be set so as to encounter the head of the bolt or stud which is being screw-threaded at the appropriate moment and thereby automatically release the disc N so that the dies are retracted automatically at the end of the screw-cutting operation.

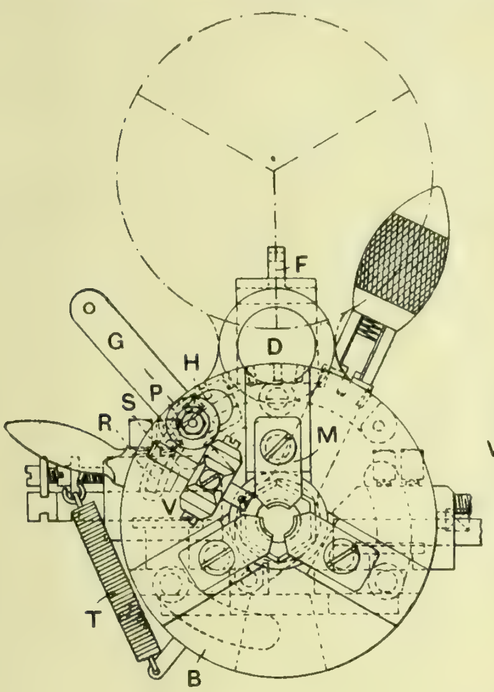


Fig. 1.

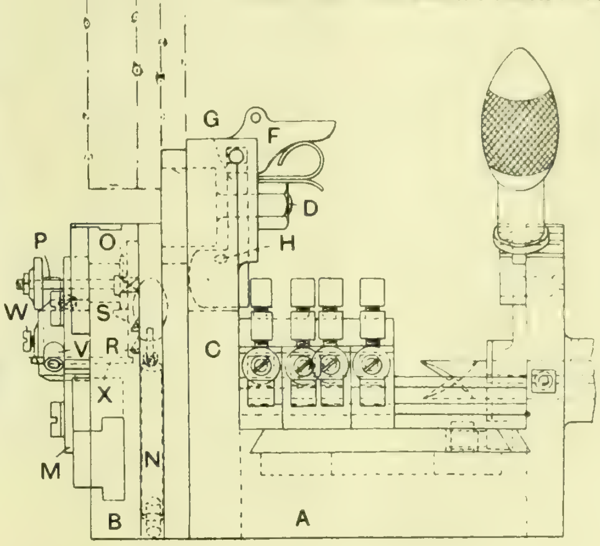


Fig. 2.

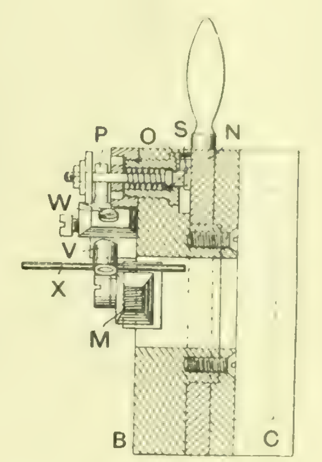


Fig. 3.

Device for Turning and Screw-Threading Metal.

Specifications for Automobile Bronzes. — The following specifications for bronzes were accepted at the recent meeting in New York of the Society of Automobile Engineers: Hard bronze, 87 to 88 per cent. copper; 9·5 to 10·5 tin; 1·5 to 2·5 zinc. Gear bronze, 88 to 89 per cent. copper; 11 to 12 per cent. tin; 0·15 to 0·30 per cent. phosphorus. The hard bronze it is explained, is identical with the United States Government bronze G, having a tensile strength of approximately 35,000lbs. per sq. in. It is offered as a general utility bronze for severe working conditions where heavy pressure and high speeds obtain, for light gears, valves, &c. The gear bronze is commonly known as English gear bronze and is serviceable for gears and worms where the requirements are severe.

THE INFLUENCE OF AIR PUMPS ON THE MILITARY EFFICIENCY OF TURBINE-DRIVEN WARSHIPS.*

BY D. B. MORISON.

THIS paper assumes a recognition of: (*a*) Military value of speed in a warship. (*b*) Tactical value of reliability in production and maintenance of maximum speed, according to the requirements and expectations of the commanding officer. In the equipment of a steam turbine installation there is no auxiliary engine which has a more important bearing on a warship's speed than the air pumps of the condensing plant. This importance arises because of the influence of vacuum on propelling power, and because it is air-pump efficiency which, under given conditions, enables the

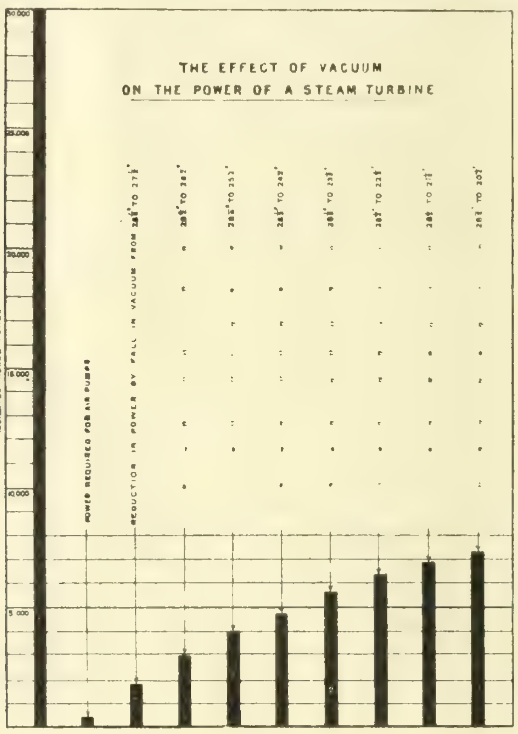


FIG. 1.

condenser to produce the highest vacuum obtainable, and air-pump sufficiency which enables such vacuum to be maintained when air beyond the normal quantity is present in the condensing system.

The degree of vacuum at which any turbine will develop its maximum power with maximum economy depends on the design of the turbine, and the detail design is determined by the compromise best suited to any given range of conditions such as temperature of sea water, weight, space occupied, &c. According to latest cruiser practice, a vacuum of 28½in. is required at full power in sea water at 55°, and, provided that the turbine is bladed to make adequate response in power to such a vacuum, then Fig. 1 shows the loss in power which results from a fall of vacuum.

The source of power is, of course, the boilers, and, therefore, the maximum power obtainable depends primarily on the quantity of steam which can at any time be generated. But if under conditions of maximum and constant generation of steam in the boilers the vacuum falls from 28½in. to 27½in., then the immediate loss in power is about 6 per cent., or, say, 1,800 i.h.p. in a cruiser of 30,000 i.h.p. In warship practice the exhaust steam from all the auxiliary engines is discharged into a receiver, and at full power is maintained at 25lbs. pressure. Apart from its employment in an evaporator, the heat in this steam can be utilised to the best thermal advantage in raising the temperature of the feed water, and the most advantageous use that can be made of any surplus is for power production in the low-pressure section of the main turbine. If, under full power conditions and at 28½in. vacuum, sufficient exhaust steam is available to raise the temperature of the feed to a predetermined limit, then at 27½in. vacuum there would be a surplus of such steam, because of the increased initial temperature of the condensate. If this surplus were utilised for power production in the low-pressure section of the main turbine the increase in power would be slightly under 1 per cent. Assuming, as is generally the case, that for reasons of weight and space occupied there is no feed-heating apparatus in a warship, then this increase in condensate temperature due to the lower vacuum would probably raise the steam generating efficiency of the boiler by about 1½ per cent. Therefore, even after adjusting Fig. 1 to the most favourable conditions of working, the loss due to a fall of 1in. of vacuum is still about 1,400 i.h.p. for the same weight of fuel consumed, and about 20 tons of coal per day are wasted.

The effect on the power of a turbine of steam pressure at the entry, and of vacuum at the discharge, is of interest. If it were desired to lower the steam pressure at the entry to the turbine to a point which would correspond to the loss in power consequent on a fall in vacuum from 28½in. to 26½in., it would be necessary to reduce such pressure from, say, 200lbs. to about 110lbs., other things being equal. That is to say, the pressure of steam entering the turbine would have to be reduced about 90lbs. in order to cause a loss in power similar to that which results from an increase in condenser pressure of only 1lb. The alternative effect to loss of power by a fall in vacuum is an increase in the quantity of steam necessary for the development of a given power, thereby reducing the radius of action obtainable from a given weight of fuel. The broad question of vacuum on a turbine-driven warship is, therefore, one of great military importance.

The highest vacuum that any given condenser could maintain under given conditions would be realised if no air entered the condenser. This airless state is impossible, as some air is always circulating through the system from the boiler to the boiler, and may at any time be augmented by insidious leakage through joints in the vacuum system. The primary function of an air pump is to enable the condenser to maintain within itself the nearest approach possible to the condition that would prevail were the steam airless. In practice, therefore, the minimum capacity of an air pump is determined by the quantity of air in suspension and solution in the feed water as it enters the boiler, without provision for insidious leakage from joints, glands, rivets, bolts, cocks, valves, and the like, which are included within the vacuum system.

FIG. 2.—RECIPROCATING AIR PUMPS. WET AND DRY INTERDEPENDENT SYSTEM.

The effect of insidious air leakage on the action of an air pump may be realised to some extent by the fact that one cubic inch of air at atmospheric pressure, subject to its relative temperature when augmented by water vapour, will become in a condenser at 28½in. vacuum about 50 cub. in. From this it is obvious that if the designed capacity of an air pump provides for no air leakage beyond what enters the system with the steam, then any such leakage, no matter how small it may be, will cause a fall in vacuum, a loss in

* Paper read at the spring meetings of the fifty-fourth session of the Institution of Naval Architects, March 12th, 1913.

propelling power, and a reduction in the speed of the ship. An air pump of this basis capacity may be said to have no air margin.

In land practice the electrical engineer is never without a substantial air margin on a turbine condensing plant. He has learned from experience that, at times, no matter how carefully the plant may be manufactured and the joints made, air will leak into the vacuum system, and that it is generally a most difficult and tedious process to locate the leakage.

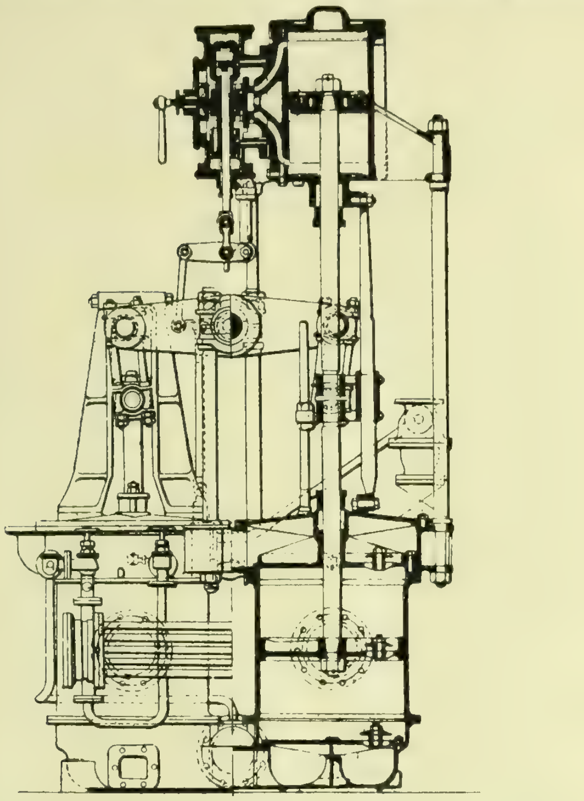


FIG. 3.—RECIPROCATING AIR PUMPS. WET AND DRY INTERDEPENDENT SYSTEM.

If the pump has no air margin the vacuum falls, the cost of producing electrical energy rises, and profits suffer. He knows that the only way of adequately providing against this loss is bv the adoption of such proportions as will deal with air leakage contingencies.

A warship presents a somewhat different problem by reason of limitations of weight, space, and economy of steam under varying loads and conditions of service, the extremes being maximum power at full speed and harbour duty at rest. The only margins allowable in this problem of obtaining the greatest power from a given weight of machinery,

provision is always made in the boiler feed system for such a contingency. In a military sense the consequences would be nil, as the speed of the ship would be unaffected. Not so with an air pump. Break down an air pump, and the warship at once becomes a slower and less reliable unit, unable to respond to the speed expectations of her commanding officer, and, in addition, there are the mechanical risks due to the extra water load to be sustained by the other air pumps which may be available for parallel working.

Fortunately, the total mechanical breakdown of an air pump is a rare occurrence, but the danger, of course, is always present. Therefore, in view of the inevitable loss in propelling power from an accident, which would in many cases affect the vacuum system as a whole, and of the consequences which might result therefrom, a reasonably adequate factor of safety becomes imperative. Next in importance to a breakdown of the mechanism of an air pump comes its breakdown in adequacy of air withdrawing capacity, should there be such a disturbance of the normal air-tightness as would cause the quantity of air to exceed that with which the air pump can deal without a drop in vacuum. It should be noted that although such a disturbance would generally affect only one section of the condensing plant, it would nevertheless have a detrimental effect on the speed of the ship.

The vacuum system comprises every part under the influence of vacuum, and what is accepted as an air-tight system is one in which every joint, gland, valve, cock, or other connection is capable of resisting the admission of any air. This condition is arrived at in practice by a process of tuning up, which means exercising the greatest possible care in workmanship, going over all the joints and connections with paint or varnish, and carefully examining every fitting, including even the cocks and union nipples of the vacuum gauges. A difficult and tedious task, as Admiralty contractors know full well. If the air pump capacity of the ship is determined on the basis of ideal tightness, then unless such ideal tightness is achieved there can be no improvement except by driving the air pump in excess of the regulation limit, an expedient which is admittedly unsatisfactory. The all-important question is: Will ideal air-tightness be maintained under the severe conditions of war, and, if not maintained, can the possible leakage at once be located and stopped? My reply, based on long experience with high vacuum plants of the highest class, would be in the negative, as I have found it futile to expect continued maintenance of ideal tightness. Insidious leakage always commences, and the invariable opinion of engineers in charge of high-vacuum plants is that air leakage is sooner or later inevitable and generally very difficult indeed to locate. If such is the position on land, what may be expected

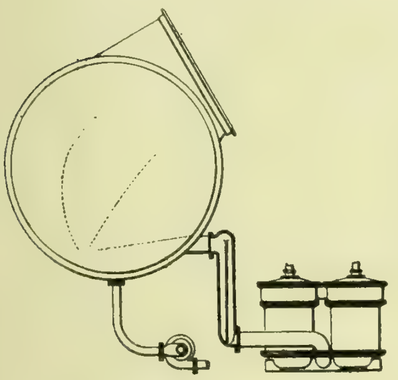


FIG. 4.—SEMI-ROTARY SYSTEM OF AIR PUMPS.

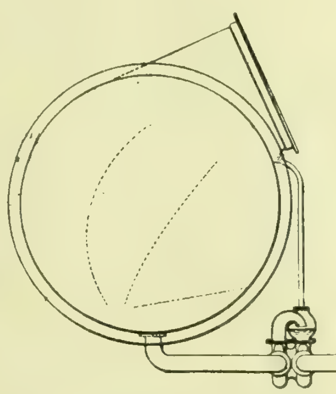


FIG. 5.—CONDENSATE PUMP. HEAD AND PRESSURE SYSTEM.

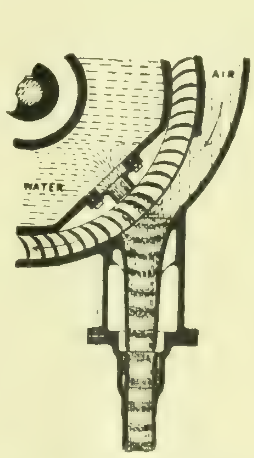


FIG. 6.—ROTARY AIR EXTRACTOR WATER TURBINE SYSTEM.

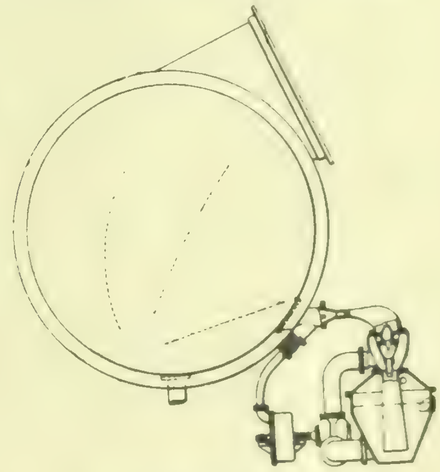


FIG. 7.—AIR WITHDRAWN BY COMBINED STEAM AND CONDENSATE JETS.

and a given quantity of fuel, are those which are essential to efficiency and safety under the most severe conditions in actual warfare.

Compare, for instance, the conditions of the feed pumps with those of the air pumps on a warship, and the relative consequences in the event of a breakdown, in action, of a feed pump and an air pump. If a feed pump breaks down entirely there is merely a temporary inconvenience, as ample

under the severity of the conditions of vibration, shock, and stress certain to be associated with a naval action? Under peace conditions the position never becomes serious, as the standard of maintained excellence on a warship is extremely high, as is also the standard of the *personnel*. It is in war time that this question will become acute. The endurance of every man has its limit, and what the physical condition of the engineering *personnel* after a few days of war in deadly

earnest will be is a question the reply to which we all pray may be long deferred. I would here refer those to whom my fears may appear exaggerated or groundless to Fig. 1. In the next naval war in which modern ships are engaged it will be reliability of performance which will tell. It is not enough that a ship has travelled at her designed speed; it is rather that such precautions are taken that she will travel at that speed when required, notwithstanding trifling departures from the normal.

Having set forth the essential contention of this paper, it will be useful to refer in a general way to types of air pumps which embody distinctive features, in order to ascertain to what extent an air margin can be provided consistently with the exacting requirements of the problem. The air pumps in the British Navy are of the reciprocating type, although a rotary one, on the kinetic principle, was recently fitted on

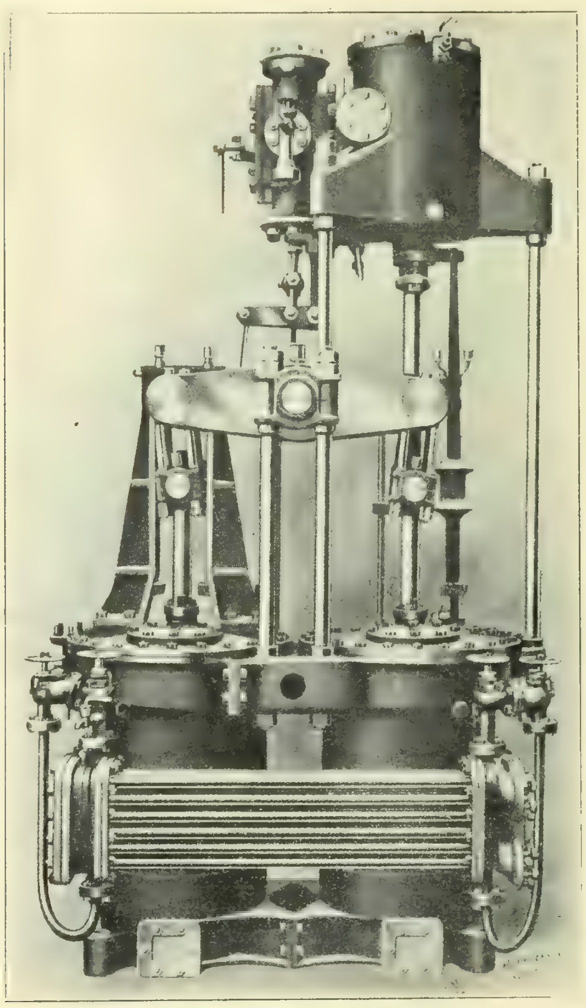


FIG. 8.

a torpedo-boat. In 1908 the writer, in a paper to this Institution, on "The Influence of Air on Vacuum in Surface Condensers," dealt at length with the advantages obtainable by what is known as a "cooled dry air pump."

In 1909 the Admiralty adopted the air pump shown in Fig. 2. It consists of twin wet and dry reciprocating pumps of the ordinary foot-and-bucket valve type driven by one steam cylinder and levers in the ordinary way. The wet barrel withdraws the water and the so-called dry barrel the air, the feature of interest being that the air delivered by the dry barrel into its discharge chamber passes through a loaded valve into the wet barrel between the bucket and the delivery valves, and is discharged thence with the condensate in the ordinary manner. This valve is loaded to 4lbs. per square inch, and, therefore, the load on the bucket of the dry barrel is lessened, thus favourably influencing the power required. The air-withdrawing capacity of the dry barrel is practically unaffected by the reduction in discharge pressure, and in this system the pumps are not independent.

Fig. 3 represents another system of wet and dry reciprocating air pumps. The wet and dry barrels, the water-cooling arrangement, and, indeed, all details, are broadly similar in Figs. 2 and 3, except that in Fig. 3 the dry pump delivers direct to the atmosphere. The wet and dry barrels are, therefore, independent in every way, so that in the event of the breakdown or derangement of either pump, the other can withdraw both air and water from the condenser. The vapour withdrawn from the condenser with the air and discharged by the dry pump as water may be taken from the discharge chamber by a small plunger pump driven from the lever and delivered to the feed tank or elsewhere as desired.

In each of these systems (Figs. 2 and 3), the whole of the water is withdrawn from the condenser by the wet barrel, and as the amount at full power is considerable and in a seaway erratic in supply, it follows that the speed at which the pumps can be driven with safety is governed by the water considerations of the wet pump. This is termed the Admiralty limit speed, and must not be exceeded on a warship full-power trial.

Fig. 4 shows a semi-rotary system whereby the water is withdrawn by a small rotary pump, working in combination with reciprocating pumps, thus rendering both barrels of the reciprocating pumps available for withdrawing air. When in harbour, or when cruising at low speeds, the rotary pump may be stopped and the water and air withdrawn on the wet and dry system as in Fig. 3. Fig. 4 also shows a safety device placed between the rotary and reciprocating pumps, so that in the event of a sudden stoppage of the rotary pump the water would be automatically and gradually delivered to the reciprocating pump, thereby preventing shocks. This safety device is of value in combination with any reciprocating water extracting pump, particularly in a heavy seaway, when sudden gluts of water are inevitable.

The semi-rotary system (Fig. 4) involves the use of a centrifugal water-extracting pump driven by either a small steam turbine or an electric motor. For a condenser dealing with steam from a 10,000 h.p. main turbine, the horse-power would, even with a considerable margin, not exceed 10. What are the advantages? For example, take the air-withdrawing capacity of a pair of wet and dry pumps (Fig. 2) at the regulation number of strokes per minute. The air-withdrawing capacity of a set of pumps on the semi-rotary system with the same diameter and stroke is increased by about 50 per cent. Moreover, in the semi-rotary system, as both barrels draw air only, and each barrel is supplied with a constant and uniform quantity of sealing water per stroke, the regulation number of strokes per minute can be increased by at least 50 per cent. without affecting the margin of safety and durability. Therefore, by the addition of a small centrifugal pump, the ultimate air-withdrawing capacity is more than doubled. Another feature of advantage is that even under conditions of extreme severity, for instance, at full power in a heavy seaway, the factor of safety on the reciprocating air-pump mechanism is constant. There are neither shocks nor jars due to gluts of water in irregular supply, the working of the pumps is smooth and regular, and is totally unaffected by variable quantity of condensate. In harbour, or when it is not necessary to work the rotary pump, the operation of a change valve enables the reciprocating pumps to be converted from parallel working as dry air pumps into the wet and dry system, whereby the air pump duty under light loads is maintained with a minimum consumption of steam.

Fig. 5 shows a type of "head and pressure" condensate pump, which is very reliable in practice. There are two impellers—the first discharges into an air-separating chamber at or about the normally maintained suction level of the second pump. From this chamber extends a vertical stand-pipe, which is connected at the top to the condenser. No lodgment of air is possible in this pump. It will work under a suction head of as little as from 6in. to 9in., and is designed to meet marine requirements. The steam economy of such a small turbine as 10 b.h.p. is low, so that an alternative drive for this pump would be by an enclosed waterproof electric motor, thereby favourably influencing the steam consumption. There can be no question as to the great increase in air capacity obtainable by this semi-rotary system, and notwithstanding all that Fig. 1 may mean to a warship, it might be legitimate to reduce the size of the reciprocating pumps by an amount which would compensate in part for the weight of the small centrifugals. That, however, is a question which must be left to the decision of naval experts. Another feature of this semi-rotary system is that it can be fitted to existing ships

with a minimum of disturbance and cost. Whenever the system is tried in this manner the advantages at full power, and especially in a seaway, will be found to be very considerable when compared with the pure reciprocating system, the inherent defect of which is the extremely low volumetric efficiency of the wet barrel as a withdrawer of both air and water.

The designer of warship machinery when considering any new development naturally hesitates before recommending a radical change, as there are so many requirements which have to be met, but the semi-rotary system of air pumps involves not so much a change as an addition, viz., a very small motor-driven centrifugal added to known and existing air-withdrawing apparatus. By means of this small addition the available air capacity at the full speed of the ship is more than doubled; the factor of safety of the existing mechanism is considerably increased, and the admitted steam economy for harbour duty is retained. Moreover, the semi-rotary system is a step forward towards the realisation of the complete rotary system in that it enables experience to be gained on an essential part of the complete rotary system, viz., the rotary water extractor. Suppose, for instance, on a 30,000 h.p. cruiser there were four such centrifugals weighing collectively with pipes four tons; again, suppose a fall in vacuum by air of only 1in. Such a fall would involve an effective loss of about 20 tons of coals per 24 hours, or five times the weight of the apparatus. In other words, the entire weight of the apparatus would be represented by the coal wasted in 24 hours by a fall of about ¼in. in vacuum, caused by insufficient air-pump capacity.

Sir Charles Parsons' well-known system of combining a steam jet air-withdrawing device with a reciprocating air pump, the steam from the jet being condensed in an intermediate surface condenser, has frequently been described in the Transactions of this Institution, and is well known to be a highly efficient apparatus.

Fig. 6 shows in diagrammatic outline a rotary air pump which withdraws the air by water films discharged from a turbine wheel. If sea water is used for air-expelling purposes the water resulting from the condensation of the vapour necessarily withdrawn along with the air is lost. Another feature is that the theoretical limit of vacuum is not the barometric pressure but the vacuum corresponding to the temperature of the sea water used for air-expelling purposes.

Fig. 7 shows a complete rotary system whereby the air is withdrawn and discharged by means of the kinetic energy of combined steam and water jets. It is in extensive use on land, and has been sanctioned and is under construction for one of the light armoured cruisers at present building. An outstanding feature of the apparatus is that the air-expelling medium is the condensate, so that the entire heat of the steam jet, together with the vapour withdrawn from the condenser, is absorbed and conserved. There is no loss of heat and no loss of water; in fact, neglecting radiation, the thermal efficiency of the system is unity, and, what is very important, the basis limit of rarefaction by the apparatus is the barometric pressure. The condensate is withdrawn by a centrifugal pump, and passes into a circulating receiver, from which it flows to the feed tank. The air is withdrawn from the condenser by a steam jet, and the aërated steam is discharged into a chamber in which condensate is sprayed by multiple jets, thereby presenting a large water surface by which the steam from the jet is condensed, and on which the air is, as it were, automatically deposited. The resultant highly aërated water is delivered to an annular water jet in the base of the chamber by which it is discharged. An ordinary centrifugal pump draws water from the circulating receiver and delivers it to the spraying jets and to the annular air-expelling jets. The steam jet is supplied from the closed exhaust system, therefore the apparatus becomes in effect an exhaust steam feed-water heater, but before heating the water the exhaust steam is usefully employed in withdrawing the air from the condenser. The centrifugal pump is driven by a small turbine, there being no other moving mechanism whatever. In a 30,000 h.p. cruiser there would be, say, four sets of apparatus, the water horse-power of each set being about 30.

It is well known that the steam consumption per horse-power of small steam turbines is high compared with that of a reciprocating engine, such as is used for driving the wet and dry reciprocating pumps, but when exhausting into the usual closed exhaust system about 70 per cent. of the work of which the steam as delivered to the small turbines was originally capable, is still available for generating power on the low pressure section of the main propelling turbine. In this connection it may be mentioned that the exhaust from the small turbine is dry, so is in an eminently suitable condition for admission to the main turbine, whereas the exhaust from the reciprocating engine is super-saturated. The apparatus is fascinating, because it is completely rotary, and, being so, it is uniform with the main turbines; it is also very simple. As a remover of highly rarefied air, such, for example, as is associated with 28½in. vacuum, it is ideal. The air capacity of the four sets referred to is, at 28½in. vacuum, more than double that of the ordinary installation of wet and dry reciprocating pumps usually fitted on a 30,000 h.p. cruiser. The system is essentially one for vacua over 26in., and the higher the vacuum the more strikingly efficient it is, provided in all cases the condenser is of suitable design.

In order to obtain reliable data a very exhaustive series of tests has been made on the reciprocating air pumps (Fig. 8). The design meets Admiralty requirements, and is in accordance with recognised first-class practice. The method of testing adopted was the usual one of withdrawing from a receiver into which air is admitted in known quantity, and through which water passes in known quantity, and at known temperature. The results obtained from such tests are, of course, not identical in a quantitative sense with what might be expected from a condenser in actual operation; they, nevertheless, permit of exact comparisons being made.

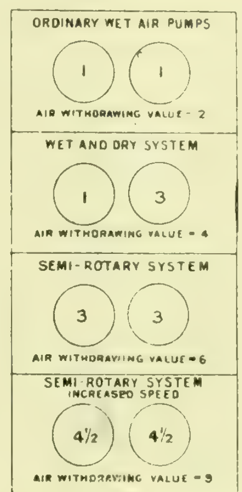


FIG. 9.

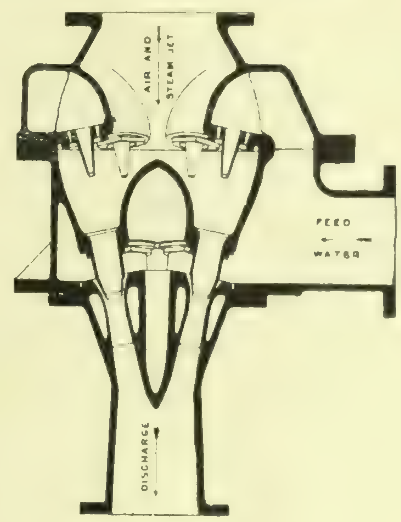


FIG 10

The pumps were arranged to work on the following systems: (*a*) Water withdrawn by wet barrel and air by dry barrel, both discharging to atmosphere. (*b*) Water barrel discharging to atmosphere and air barrel against pressures below atmospheric. (*c*) Both barrels withdrawing air in parallel as in semi-rotary system.

The temperature of the water passing through the wet barrel ranged from 70° to 120°, and that passing through the dry barrel from 50° to 90°, thereby covering all the conditions met with in practice.

Referring again to the basis example, viz., 28½in. condenser vacuum with 55° sea water, and assuming the condensate to be 80°, the conclusions are as follows: The air-withdrawing capacity of the dry barrel is about three times greater than the wet barrel. There is no measurable difference in the quantity of air withdrawn by reducing the discharge pressure from atmospheric to, say, 5lbs. absolute. If both barrels are worked dry in parallel, as in the semi-rotary system, the air capacity per minute is one-half greater than on the wet and dry system at the same number of strokes per minute. With both barrels working in parallel as air barrels at a number of strokes per minute 50 per cent. greater than the regulation strokes permissible on the wet and dry system, the smoothness of working is at least equal to that obtained by the wet and dry system at the regulation strokes, and at this increased speed the air withdrawing capacity is more than doubled (Fig. 9.)

Fig. 10 is a section of the apparatus on which experiments were made on air withdrawal by the kinetic energy of steam and water jets. The temperature of the condensate was again assumed to be 80°, and 5° were added for heating by the steam jet, so that the temperature of the water in the circulating tank was maintained throughout the tests at 85°. The water horse-power of the centrifugal pump supplying the jets was 33. With no air separately admitted, and with water at 85° passing through the jets a vacuum of 29·8in. was maintained with barometer at 30in. A vacuum of 28½in. was maintained under the above conditions with an air admission of 50 cub. ft. per minute. A vacuum of 28in. was maintained under the above conditions with an air admission of 65 cub. ft. per minute. This result is beyond the requirements of ordinary practice, and was made to illustrate the possibilities of the system.

Having reviewed the broad question of air margin for air pumps, the proposition I venture to submit for consideration is as follows: There is an ascertainable and minimum quantity of air passing through a turbine system to the boiler as air in suspension and solution in the feed water, and from the boiler into the condenser as air in the steam, this quantity being based on the assumption that the joints, &c., in the vacuum system are absolutely airtight. If at full power the capacity of the air pumps at the specified vacuum is based on this quantity of air, the pumps may be said to have no air margin. In view of the influence of vacuum on power and of the influence of microscopic air leakages on vacuum, is it or is it not desirable to provide warship air pumps with an air margin at full power, and if so, what should the air margin be, relatively to the normal quantity of air passing through an air-tight system per unit weight of feed water?

In conclusion, I may say that my endeavour has been to set forth within the limits of a paper the influence of an air pump on the military efficiency of a turbine-driven warship. It is a subject which should appeal alike to the naval constructor, the naval engineer, and the commanding officer. Its consideration brings into prominence the far-sighted policy of the new scheme of naval training whereby all the officers in H.M. Navy will have passed through an engineering course and be able in the future to review professionally the many subtle problems involved in that wonderful aggregation of mechanism, a modern warship.

Military Aviation. — Major F. H. Sykes, Commandant of the military wing of the Royal Flying Corps, in a lecture on "Military Aviation," recently delivered before the Aeronautical Society of Great Britain, said it had been remarked that the nation which got command of the air would gain the victory, and although that might be the case in a few years hence, he did not think that was correct at the present time. He thought that the command of the air would never be the same as the command of the sea or land. It had been suggested that it would be better to develop some aeroplanes along the line of light fast scouting machines, and it was certain that such machines would have an advantage. It would perhaps be necessary to develop British airships along naturally characteristic lines in the same way as they had done in the matter of ships in the Navy. What was wanted now was first of all for strategical work a single seater scout aeroplane with a speed of 90 miles an hour and a landing speed of half that figure, a very high rate of climbing, and a petrol capacity of about 300 miles. Good view was also essential. Secondly, they wanted a two-seater with a speed of 80 and 40 miles per hour, and a 200 miles tankage, carry a light weapon, a good climber, and capable of landing on bad ground. Thirdly, a two-seater fighting machine with speeds of 70 and 40 to carry a gun, ammunition, and light armour, and petrol for 200 miles. Fourthly, a semi-rigid airship of about 250,000 to 300,000 cubic feet, a speed of 55 miles an hour, and capable of keeping in the air for at least six hours to carry a crew of eight, a light gun, and "wireless." He looked in the not far distant future for scouting aeroplanes of 120 miles an hour, "fighters" to carry a pilot and assistant gunners and observer at 100 miles per hour, weight-carriers to transport troops, rations, and equipment 10 or 12 at a time a distance of 30 miles and make five trips a day.

INDUSTRIAL AND TRADE NOTES.

Extension of Harland & Wolff's Works.—The Belfast Harbour Board have granted a lease to Harland & Wolff of 15 acres additional land, for the purpose of extending the firm's engineering works. It is understood the capacity of the works will be doubled, giving employment to about 3,000 additional hands. To erect and equip the new works will cost about £200,000.

Airships for the Admiralty.—Messrs. Vickers, Ltd., Barrow, have, we understand, received instructions from the Admiralty to build the second Parseval airship. This firm have already had considerable experience in airship building, and the Admiralty's intention is that all future airships shall be built in the United Kingdom. The Admiralty have been waiting for an approved design of airship, and now the Parseval has been accepted it is likely that many similar craft will be built.

Oil Engines for Ship Propulsion.—At the recent annual meeting of Swan, Hunter, & Wigham Richardson & Co., Ltd., Dr. G. B. Hunter said they were building a new graving dock on the Tyne, costing between £50,000 and £60,000, which would be opened early next year. They were proceeding further in the matter of internal combustion oil engines, and were constructing an interesting vessel, to be named the "Tynemouth," in which oil would be used to generate power, which would be applied to the propelling shaft through electric motors.

Trade Circulars and Catalogues.—We have received the following trade circulars and catalogues: Aiton & Co., Derby, an illustrated catalogue and price list of flanged pipes and accessories; Ozonair, Ltd., 96, Victoria Street, London, S.W., descriptive pamphlet of their system of ventilation; The General Electric Company, 67, Queen Victoria Street, London, E.C., illustrated catalogues and price lists of Holophone pendants, telephones, fire alarms, water-level indicators, &c.; Meldrums, Ltd., Timperley, near Manchester, descriptive circular of their forced-draught furnaces, mechanical stokers, and refuse destructors.

Working Model of Mather & Platt's Duplex Gas Engine.—We have received from Messrs. Mather & Platt, Ltd., Manchester, an interesting working cardboard model of their duplex patent valveless gas engine. The model, which shows sections of the cylinders and valve arrangements, and is operated by the turning of a cardboard disc, demonstrates the special features of the engine far more clearly than could be done by any amount of description. We commend the model to the attention of science teachers, as an illustration of one of the latest developments in gas engine design, by which the two pistons obtain an impulse at each stroke, while every stroke is a driving stroke. We may add that the model is issued at the price of 2s. 6d.

German Shipbuilders' Loss.—The report of the management of the Vulkan Shipbuilding Company, of Hamburg and Stettin, was presented at a meeting of the directors at Hamburg on Saturday last. It states that the vessels completed for the German Navy in 1912 by the company had resulted in a loss to the company amounting to £100,000. Orders for ships of a large type from the Navy and from mercantile shipowners were always given terms involving a loss to the builders. That the company was able to pay a dividend of 6 per cent. was declared to be due not to the favourable results of the previous year, but to the reserves built up in the past, when it was still possible to obtain orders under normal conditions.

Casualties in Factories.—According to a White Paper just issued by the Home Office, there were 656 cases of industrial poisoning (including 50 deaths), 1,260 fatal accidents, 155,750 non-fatal accidents, and 1,557 dangerous occurrences other than those regarded as accidents in factories and workshops last year. These figures, however, are only preliminary, and are liable to correction. In 1911 there were 755 cases of industrial poisoning, 1,182 fatal accidents, 148,735 non-fatal accidents, and 966 dangerous occurrences. Among the diseases scheduled under industrial poisoning the largest number of workers—namely, 587—were attacked with lead poisoning. Forty-four of the cases proved fatal. The breaking of hoisting appliances was responsible for 1,082 dangerous occurrences.

French Iron and Steel Industry.—According to the "Frankfurter Zeitung," the production of pig iron in France during 1912 reached 4,826,000 metric tons, compared with 4,426,000 metric tons in 1911. This increase of 400,000 metric tons is accounted for by the working of eight new blastfurnaces and the increased output of existing furnaces. Of the 159 blastfurnaces in France 131 are in operation, compared with 123 at the beginning of 1912, and 114 at the commencement of 1911. Everything points to a still further increase in the production of French pig iron during this and the next few years. In the east of France alone 12 new blastfurnaces will be taken in hand during the present year. The production of finished iron and steel products has also considerably

increased during the past few years. A noteworthy fact in connection with the increased production of iron and steel products during 1912 is that almost all the increase was absorbed by the home markets.

Iron and Steel Industry in New Zealand.—His Majesty's Trade Commissioner for New Zealand has forwarded a copy of the report of the Select Committee of the New Zealand House of Representatives, which was appointed to consider the question of the establishment of an iron and steel industry in the Dominion, with special reference to the proposals of a London syndicate for the development of the iron ore deposits at Parapara and Omakaka. The Committee decided that it is desirable, in the interests of the Dominion, to encourage the production of iron and steel from native ores. The proposals of the syndicate were, however, considered unsatisfactory in their present form, and their acceptance was not recommended. The Committee recommended that the Government should make a full enquiry into the whole matter at the earliest possible date, with a view to ascertaining the terms on which investors would be prepared to provide the capital necessary to develop the industry on an adequate scale. As an alternative, it was suggested that the Government should fully enquire into the advisability of developing the industry as a State enterprise.

British Engine, Boiler, and Electrical Insurance Company, Ltd.—At the annual meeting of this company, held at the Head Office, 12, King Street, Manchester, on Friday, March 7th, the Chairman (Mr. R. Charles Longridge) mentioned that in the course of the past year the Royal Insurance Company, Ltd., had acquired a controlling influence by the purchase of shares, and in consequence of advancing years his father, the first chairman of the company, had taken this opportunity for resigning his position on the Board. Mr. Moss, also, who had been secretary almost from the commencement of the company, was retiring from that position, and his place would be taken by Mr. H. F. Taylor, who had for many years represented the company in Glasgow, but these changes involved no alteration in the operations of the company, and had in no way interfered with its progress. Claims showed a considerable increase as compared with 1911, and this was chiefly among steam engines, possibly because trade was so good that engines were overburdened, but that explanation would not account for the fact that in spite of a great increase in the number of electrical machines insured the claims in that department had not increased. He ventured to hope that this improvement was due to the educational advantages derived from the repeated visits of the company's inspectors, when they explained to attendants—many of whom knew little or nothing about electricity—what should be done to keep machines in good working order. While the amount to be paid for claims was about the same, the ratio of breakdowns also remained nearly constant, namely, one out of every nine machines insured. There had been a considerable diminution in claims for boilers, and the general results spoke well for the efficiency with which the work of inspection had been carried out. It was resolved to pay a dividend of 5s. per share, with a bonus of 3s., and after re-election of directors and auditors the meeting ended.

Conference on Shipyard Wages.—A conference was held at Carlisle on the 7th inst. between representatives of the Shipbuilding Employers' Federation and the shipyard trade unions to discuss the wage question. The Standing Committee of the Shipyard Unions applied for an advance of 5 per cent. on piecework and 1s. per week or ¼d. per hour on time work, on the wages rates of all the shipyard members of the unions. It was argued that the continued good trade and the scarcity of workmen justified them in asking for the advance. On behalf of the employers it was urged that trade conditions did not warrant an advance of wages. There were decided indications, they said, that the industry had reached its highest point. There were now very few enquiries for new boats, contracts were difficult to obtain, there was keen competition for the work that was in the market, there was a marked falling off in freights, and everything pointed to a decline in the demand for new tonnage. In these circumstances they did not think they should be expected to grant an advance of wages, which would increase costs still further, and thus render it more difficult for them to obtain new work. Ultimately the discussion closed on the understanding that the employers had declined, at that "preliminary" conference, to admit that there was a case for the advance, and that the Standing Committee would, in accordance with the procedure of the national agreement, ask for another conference within a fortnight to discuss the matter in greater detail. After the conference with the Standing Committee the employers met the Executive Council of the Boilermakers' Society and discussed with them the question of a 5 per cent. advance on wages. The discussion was on similar lines, and the result was the same, the employers declining to admit that an advance would be justified, and the men's representatives having the option of allowing their application to lapse or asking for a further conference.

PROCESS FOR THE PRODUCTION OF TOOL STEEL.

A NEW process for the production of steel of high quality by clearing *in vacuo* forms the subject of a patent recently granted to The Dellwik Fleischer Company, 5, Marienstrasse, Frankfurt a.M., Germany. It is well known that molten steel is much improved if an opportunity is given for the gases and particles of slag in it to be separated, and that this separation or clearing can be especially accelerated if the fluid steel is exposed to a vacuum. It is also very important that during this clearing period the steel should be protected against cooling as much as possible, so that it may retain its fluidity as long as possible. For this reason the clearing vessel is placed during clearing in another container or in a pit which is itself exhausted. In this way a vacuum is formed around the vessel which actually contains the steel, and that, as is well known, gives the best possible protection against loss of heat. However, loss of heat to some extent is unavoidable, and according to the process under notice in order to compensate for this unavoidable loss of heat, and especially in order to gain a considerable reserve of heat for purposes of regulation, all the surfaces of the actual clearing vessels, as well as of the vacuum containers, are highly heated beforehand, for example, with a water-gas flame, preferably to the melting point of the metal. For this purpose all the surfaces are lined with heat-insulating refractory material, for example, chamotte.

In carrying the process into effect, the fluid steel is placed in one or more large containers. The steel is then allowed to rest quietly in these clearing vesels for a long time so that it may clear before it is poured out. For this purpose, iron containers are employed lined with refractory material, and of such dimensions that there is sufficient space in them for the clearing vessels. These containers (which are suitably sunk in pits) have a turned flange upon their upper edge upon which a similarly flanged cover is fastened in air-tight fashion by means of packing material. If now the clearing vessel, after having its surfaces highly heated, preferably to the temperature of fusion of the steel, filled with fluid steel and loosely covered with a cover of chamotte, is put into such a pit container, the interior surfaces of which are similarly highly heated, and the cover of this latter then fastened on air-tight, and the pit exhausted, some very important advantages are simultaneously obtained. In the first place, the vacuum powerfully assists the separation of gas, so that the clearing process is not only improved in quality, but the time taken by it is diminished. But besides this the large interior surface of the vacuum chamber, together with the surfaces of the clearing container, constitute a heat storer of very great capacity, and also the vacuum around the clearing vessel diminishes the loss of heat by conduction so considerably that there is no fear of the steel becoming viscous, even if the clearing vessel is in the exhausted pit for hours. Moreover the use of the exhausted pit enables the clearing process to be thoroughly completed without disturbance. In particular the clearing process is a process of refining as well suited as it is cheap for ordinary Bessemer or Martin steel, because it most efficiently and thoroughly effects the separation of the gases from fluid steel and molten iron, which now, as is well known, diminish the quality of the product. For the melting of steel in a Martin furnace it is desirable that a gas flame of high temperature of combustion free from ashes and sulphur should be used, and for this purpose water gas is particularly to be recommended for the preliminary treatment of the material which is to be treated, as well as for heating the refractory surfaces.

BOOKS RECEIVED.

The Electron Theory of Magnetism. By Elmer H. Williams Bulletin No. 62, University of Illinois. London: Chapman and Hall. Price 35 cents.

Journal of the Institution of Electrical Engineers, No. 217. Vol. 50, Feb., 1913. London: E. & F. N. Spon. Price 5s.

How to Read a Drawing. By Vincent C. Getty. London: J. B. Lippincott Company. Price 4s. 6d. net.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 58, New Bailey Street, Manchester.

MECHANICAL, 1911.

Valves for internal-combustion engines. Sears. 25451.
Creating motive power by hydraulic and atmospheric pressures combined. Legrand. 25572.

1912.

Variable-speed gear. Bowden & Raven. 1104.
Manufacture of tungsten. Johnson. 1161.
Preliminary heater in connection with furnaces for the reduction of zinc ores. Roitzheim. 1338.
Manufacture of double helical metallic tubing. Davies & Judge. 1611.
Turbine installation for ships. Stettiner Maschinenbau Akt.-Ges. Vulcan. 1668.
Apparatus for the softening and purification of water. Water Softeners, Ltd. 3671.
Carburetter for petrol or oil engines. Girling. 3696.
Steam engines. Ferguson. 3717.
Carburetters for internal-combustion engines. Megevet & Picker. 3757.
Pneumatic driven hand actuated tools. Greig. 3770.
Fuel feed apparatus for oil engines. Johnston. 3784.
Automatic couplings for railway vehicles. Allison. 3857.
Big ends of multi-cyclinder radial rotary fluid pressure engines. Peet. 3868.
Apparatus for indicating the direction of rotation of shafts. Keppie & Maddick. 3878.
Device for governing steam turbines. Vereinigte Dampfturbinen Ges. 3931.
Lubricators. Preston. 3954.
Self-starting apparatus for internal-combustion engines of the multi-cylinder type. Ashford. 4099.
Silencer for internal-combustion engines. Dawson & Dawson. 4136.
Two stroke cycle internal combustion pumps. Akt.-Ges. Brown, Boveri, et Cie. 4158.
Furnaces. Sillery. 4163.
Two-cycle internal-combustion engines. Nordstrom. 4168.
Lubricating apparatus. Maranville. 4243.
Process for the manufacture of briquettes from coal waste. Efrem and Efrem. 4377.
Aeroplanes. Austin. 4378.
Two-stroke cycle internal-combustion engines. Marks. 4459.
Internal feed-water heater and purifier. Green. 4727.
Water-tube boilers. Stirling Boiler Company, and Constantine. 4753.
Method of preventing the formation of boiler scale. Brazda, Schuckher, & Richter. 5246.
Smoke-consuming furnaces. Kowitzke. 6674.
Two stroke cycle internal combustion engines. Kemp. 7103.
Carburetting devices of the internal-combustion engine type. Brewer. 7170.
Stop or cut-off valves. Lindsay & Pollock. 7564.
Internal-combustion engines. Haddan. 7713.
Provisions for supply of fuel in certain types of internal-combustion engines. J. Samuel White & Co., and Sillince. 8060.
Refining process for iron and steel by means of ferro-chrome alloy. Buchel. 8479.
Rotary valve mechanism for internal-combustion engines. Jaeger. 9549.
Automatic regulation of feed of liquids for supplying carburetters. Constantinescu. 10037.
Centring appliance for use in conjunction with lathes. Stubbs and Hartley. 10596.
Boring or drilling machines. Robertson. 10961.
Lubricating device for wheels and pulleys. Hilbert. 11361.
Manufacture of aluminium carbides. Peacock. 11391.
Distributing and cut off valves for fluid pressure motors. Nichols and Nichols. 11603.
Apparatus for analysing gases. Hufner. 11679.
Liquid level indicators. Hawkins. 12461.
Protection of metal surfaces. Continental Caoutchouc und Gutta Percha Cie. and Willenius. 12753.
Lathe tool holder. Swinburne & Crawford. 12812.
Ratchet stocks for screwing dies. Robson, Robson, Robson, and Robson. 13472.
Roasting furnaces. De Lummen. 13549.
Hammering machines for use in stamping and planishing metals. Kremiansky. 13642.
Carburetters for use with fluid pressure engines. Rotherham and Johnson. 15653.
Gas turbines. Ungar & Gabryel. 15770.
Combustion engines. Winnier. 15911.
Method of treating metal ingots. Benjamin. 16093.
Friction clutches. Fornaca. 16531.
Method of and apparatus for regulating 2 cycle internal combustion engines. Fornaca. 17402.
Blast pipes of locomotives. Heller. 18416.
Motor road vehicles. Joseph. 18601.
Valve operating gear for internal combustion engines. Barnard, Griffen, & Pope. 19004.
Winches. Clarke, Chapman, & Co., and Walker. 19411.
Dog clutch. Puddicombe. 19549.
Motors for operating reciprocating conveyers. Eickhoff. 19696.
Spanners. Richards. 21550.
Internal combustion engines. Kieling. 21950.
Pneumatic hammers. Soc. Anon. d'Explosifs et de Produits Chimiques. 22741.
Safety valves. Cockburn & MacNicoll. 23336.
Treatment of the exhaust gases of internal combustion engines. Von Eicken. 23420.
Flexible shafting. Plank. 24744.
Builders' cranes. Jb. Merz & Co. 26455.
Variable speed hydraulic transmission gears. Bellens. 28665.
Steam engine cylinder. Schmidt. 28766.

1913.

Toothed gearing. Dawson & Buckham. 407.
Starting of internal combustion engines. De Jarny, and British Motor Cab Company. 2457.

ELECTRICAL, 1912.

Mounting incandescent electric lamps and reflectors therefor. Beuttell. 1186.
Electrical installation for lighting, heating, and ventilating railway carriages. J. Stone & Co., and Darker. 4073.
Electrically-heating cooking utensils. Perry. 4090.
Dynamos. British Thomson Houston Company. 4187.
Brush holders for dynamos. Morgan Crucible Company, and Grant. 4592.
Miners' electric lamps. Worsnop. 4933.
Telegraphy. Brown. 6275.
Electric radiator. James Slater & Co. (Engineers), Ltd., and Allensby. 6864.
Clutches operated by electro magnetic coils. Richards. 7928.
Telephone exchange systems. Johnson. 8997.
Ignition devices for internal combustion engines. Brenot. 10130.
Clutches and driving mechanism particularly adapted as slow motion gears for the operation of starting devices for electric motors. Wolliscroft, and H. T. Bootroyd, Ltd. 10366.
Protective devices for electric distribution systems. British Thomson Houston Company, and Wedmore. 10545.
Electrodes for arc lamps. British Thomson Houston Company. 11792.
Magnetic water level indicator for steam boilers. Montgomery. 16483.
Electric safety fuses. Kovacs. 19218.
Device for controlling electric circuits in a determined order. Siemens Bros. & Co. 20914.
Safety devices for the cables or overhead conductors of direct and alternating current installations. Bergmann Elektricitats Werke Akt. Ges. 21831.
Electric switchboards. Vandervell & Midgley. 27501.
Method and means for protecting electric accumulators from flooding by sea water. Wehrlin. 28519.

METAL QUOTATIONS.

TUESDAY, MARCH 11TH.

Aluminium ingot	95/- per cwt.
" wire, according to sizes, &c. ......from	112/- "
" sheets " " ...... "	120/- "
Antimony ......£34/-/- to	£36/-/- per ton.
Brass, rolled	8¼d. per lb.
" tubes (brazed)	10⅛d. "
" " (solid drawn)	9d. "
" " wire	8⅜d. "
Copper, Standard	£64/17/6 per ton.
Iron, Cleveland	63/- "
" Scotch	69/- "
Lead, English	£16/ /- "
" Foreign (soft)	£15/11/3 "
Mica (in original cases), small	6d. to 3/- per lb.
" " " medium	3/6 to 6/- "
" " " large	7/6 to 11/- "
Quicksilver	£7/10/- per bottle.
Silver	26 13/16d. per oz.
Spelter	£24/10/- per ton.
Tin, block	£211/10/- "
Tin plates	14/11 "
Zinc sheets (Silesian)	£28/17/6 "
" (Stettin; Vieille Montagne)	£28/17/6 "

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Edited by
WILLIAM H. FOWLER
Wh. Sc., M.Inst.C.E.

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Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

Effect of Cross Water Pipes on Circulation in Lancashire Boilers.

We give on another page a letter from a correspondent who invites an expression of opinion from those of our readers who have experience as to the advantages or otherwise of the cross water pipes, more commonly known as Galloway tubes, which are often inserted in the furnace tubes of Lancashire and other cylindrical boilers. The matter is one on which there is considerable diversity of view amongst boilermakers, steam users, and engineers in charge, and for this reason it may perhaps be of advantage if we discuss the matter a little ourselves. The introduction of cross water pipes in the flues of Lancashire boilers may be said to date back to the invention of the Galloway boiler in 1849, which soon became popular and which, with its array of vertical pipes and extension of heating surface, was certainly calculated to convey a good impression as to its water circulating efficiency, though, like many other engineering views, it rested more upon general impression than actual experiment, for we are not aware that any reliable tests were made. However, the boiler became a favourite and remained so until the advances in pressures passed beyond the limits for which the construction of its oval flue tube rendered it suitable and which may be put down roughly at about 120lbs. to the inch, while the popular belief as to the efficiency of the tubes led to these taper water pipes being inserted to a large extent in the plain flue tubes of existing Lancashire boilers. In this way the fashion was set, and eventually, when the patent rights in connection with the taper water pipes lapsed, it became a practice for makers, when constructing a new Lancashire boiler, to insert a few cross water pipes, about four to six, in each flue tube, the tubes, however, being, as a rule, parallel for simplicity of construction. Prolonged experience in the working of these water pipes, coupled with the observations of boiler inspectors on the frequency with which these pipes often became choked with scale if the feed-water happened to be dirty, led to doubts being entertained respecting their reputed merits, though we are not aware that

any reliable tests of them were conducted until the Manchester Steam Users' Association took up the matter and published some observations of actual tests on temperature differences in mill boilers when getting up steam, along with its report on a series of red hot furnace crown experiments in the year 1890. These observations are of especial interest, in view of the questions raised in our correspondent's letter, and, as the younger generation of engineers will hardly be cognisant with the information, as the report is somewhat rare, it may be well to repeat some of the facts then brought out. The experiments were made with several boilers, both of the Lancashire and Galloway type, in ordinary practice and under various conditions. One of the Lancashire boilers had no cross water pipes in the internal flues, the other had four cross pipes in each, while the Galloway boilers had 33 conical water pipes in two cases and in a third case 30. The boilers were set in the usual way, *i.e.*, the gases after leaving the flue tubes at the back end passed under the bottom of the boiler and, lastly, along the sides, except in the case of one Galloway boiler, in which the flames, after leaving the back end, passed down the sides and, lastly, under the bottom. It is impossible here to give particulars of the various tests, suffice it that some half-score were made and careful records were taken at short intervals of the temperatures at the surface, as well as the bottom of the boiler, and of the time taken to acquire them. The observations at the surface were deduced, after a temperature of 212° Fah. was reached, from the actual steam pressure existing by the aid of a steam table. The temperatures of the lower parts of the boilers were determined by means of a thermometer inserted in the stream of water drawn off at intervals from the test tap, but these temperatures could of course not be carried beyond the atmospheric boiling point, 212° Fah. The records were instructive not only as regards the efficiency of boilers with and without cross water pipes, but also as to the slowness with which the water in mill boilers gets heated up to steam temperature, and therefore of the importance of raising steam slowly to avoid the stresses resulting from temperature differences between the upper and lower parts of the boiler. In making the tests every effort was made to avoid prejudice. The firemen were not cognisant of other tests or of their special object, but were instructed to fire gently and get up steam gradually just as if no observations were being made. While this avoided prejudice, it prevented of course exact uniformity, and thus accounts for the slight disparities in the results which were noted, though it did not affect their general tenor. The tests were made with the boilers filled to the usual working level with cold water (about 60° Fah.), tepid water (about 90° Fah.), and hot water from the economiser (about 150° Fah.). These figures are only approximate, but they are sufficiently accurate for purpose of general comparison. Coming to the results recorded, it was found—starting with cold water—that when the surface temperature reached 212° Fah. the temperature at the bottom in the case of the Lancashire boiler fitted with four cross water pipes in each flue was only 72°, *i.e.*, a temperature difference of 140°, while in the case of the Lancashire boiler without cross water pipes the bottom temperature was 96°, or a difference of 116°, whereas if the cross water pipes had been effective in promoting circulation these figures should rather have been reversed. Reasoning solely from them it might appear that the boiler without pipes promoted circulation better than the one with pipes, but we would not draw so sweeping a conclusion, since the circumstances of the tests were not exact enough for this, but the pipes certainly did not show any advantage, while a comparison of these two results with those obtained with the Galloway boilers did not show the latter to possess any superiority, for the temperature differences between the surface and bottom of the boiler, when the former reached 212° Fah., were respectively 134°, 141°, and 142° Fah. In each case these were greater than the differences observed with the Lancashire boilers, and therefore measured by them were less effective from the circulation point of view, while this was also borne out in the tests made with the boilers starting with hot water, for when 212° was reached at the surface the difference between it and the bottom temperature was only 30° in the Lancashire boiler with cross water pipes, while it was 57° and 64° in the case of two Galloway boilers. Continuing the observations at higher temperatures beyond 212° and until the surface water reached from 300° to 320° (it differed slightly in different tests) the comparison between the Lancashire boilers and the Galloways showed that the latter, notwithstanding its large number of water pipes, was from the circulation point of view less efficient, inasmuch as the temperature difference between the surface water and that at the bottom was greater. As showing the slowness with which circulation generally takes place in mill boilers it is instructive to note that by the time the water at the bottom of the boiler had reached 212° steam existed above the water level, in three cases above 70lbs. pressure and in two cases to above 80lbs. pressure, the time occupied in reaching these results ranging roughly from two to over four hours, while the greatest temperature difference recorded between surface and bottom was 236°. The late Mr. L. E. Fletcher, then chief engineer of the Manchester Steam Users' Association, concludes his report of the tests with the following observations. "It would not be fair to draw a *minute* comparison between the results obtained from the different boilers unless the temperatures of the water at the commencement of the experiments, the strength of the draught, the intensity of the fire, and all the conditions under which the boilers were worked were the same in every particular, but the following *broad* deductions may, it is thought, be drawn: firstly, that in ordinary mill boilers the temperature when getting up steam is much higher at the top of the water than at the bottom; secondly, that this inequality is practically the same whether in a Lancashire boiler with four cross water pipes in each flue tube or in a Lancashire boiler without any cross water pipes at all, or in a Galloway boiler with 33 conical water pipes and two pockets, or with 30 conical water pipes and two pockets; thirdly, that it appears that water pipes are not as efficient in promoting circulation of water throughout the boiler as the public has generally supposed. The M.S.U.A. has been very cautious in recommending the adoption of water pipes, and these experiments would appear to justify the caution it has exercised." We do not know that we can add much to this conclusion. No evidence has since been adduced to show that it should be modified, and though cross water pipes may add a little to the resistance of a circular flue against complete collapse, they interfere with the work of inspection, while, if the feed-water is dirty, the pipes are liable to get choked and overheated. In a word, cross water pipes in a Lancashire boiler only add to cost and have no special advantage.

A Large Coalfield in China.—The Chinese province of Shansi is practically one enormous coalfield, says the American Consul-General at Tientsin, in which the estimated quantity of coal is 630,000,000,000. A large portion of the province of Honan, north of the Yellow River, is equally productive. Native mines are never worked to any great depth, says the Consul, because of the water, with which the native miners cannot cope owing to their primitive machinery. Mining in Honan is a comparatively easy operation, however, as there are no very hard rock strata to pierce.

MANCHESTER ASSOCIATION OF ENGINEERS.

THE Annual General Meeting of the Manchester Association of Engineers was held on Saturday last, the 15th inst. From the Annual Report of Council presented by the Secretary (Mr. Frank Hazelton), the Association appears to be in a very flourishing and progressive condition. The past year has been notable for considerable increase in the membership and in the finances, the total number of Members on the roll now amounting to 640 and the cash balance to £6,296. The president elected for the current year is Dr. Edward Hopkinson, M.A., director of Messrs. Mather & Platt, Ltd., Manchester. On the conclusion of the formal business an interesting paper was read by Mr. A. V. Roe on "Flying Machines." It was, he said, only seven years ago that flying was considered impossible. At that time reports were coming over from America stating that the Wright Bros. had flown 20 miles, but only a few people, who had been following the Wright Bros.' gliding experiments, believed these reports or understood their true meaning. At the commencement of the 19th century there arose a great student of flight, Sir George Cayley, whose writings might be read with benefit by many even at the present day. He had very clear notions of what was required and how it had to be done. In 1809 he made a machine of 300 sq. ft. surface which apparently was quite stable in the air and would lift a man a few yards on running forward at full speed. But Sir George was in advance of his time, there being no suitable engine to help him. Some years previous to the flights by the Bros. Wright, Lilienthal, a German, had made hundreds of gliding flights from a hill. Sometimes a puff of wind would lift him up higher than the point from which he started. Lilienthal was eventually upset during one of his glides and killed. Pilcher, an Englishman, made many glides, taking up Lilienthal's work, but, unfortunately, he met with the same fate as Lilienthal. Prof. Langley was a pioneer who showed a knowledge of flying in advance of his time. A steam-driven model of his design flew about half a mile some 17 years ago. The planes were about 6 to 1 aspect-ratio, and the wings were arranged in tandem, a type of machine called a "Tandem Monoplane." Langley spent many thousands of pounds in constructing a full sized machine. He started it from a shoot-off over water, but naturally the result was disaster, though the pilot got nothing worse than a ducking. It was rather too much to expect a successful flight at the first attempt, especially in those early days. Since then pioneers have, more cautiously, started from land. Phillips, another Englishman, carried the aspect-ratio idea to extremes, but he introduced an entry edge to planes known as the Phillips entry.

The Wright Bros. began gliding experiments in 1900, only 13 years ago. Starting from the top of a gradual slope, they would float down against a wind of about 20 miles per hour. When they had mastered the art of balancing in this way, they made an especially light engine in their cycle factory, and by means of it, in 1905, made their world-famous flight of 20 miles, which was discredited by most people, except by those who had been following their work. The success of the Brothers Wright, together with the introduction of the lighter and more suitable fuel of petrol, with correspondingly improved engines, acted as incentives to many workers, whilst the early flights of Santos Dumont, in 1906, on his exceedingly lightly constructed aeroplane, acted as a further stimulus. At this period the lecturer was experimenting with models, several of which he described and illustrated by means of lantern slides. One of these models eventually won the first prize in the "Daily Mail" aviation competition in April, 1907, for the longest flight. There were over 200 entries, but only four competitors succeeded in making their models fly. The Roe biplane fitted with a 24 h.p. Antoinette engine was, he said, the first machine to fly in England, in June, 1908.

In the early days of flying difficulties were experienced in finding a suitable engine of light weight and the author referred to one of these early machines which was driven by an ordinary motor cycle engine of only 9 h.p. This motor, together with its drive, was nearly as heavy as the present-day 50 h.p. Gnome engine, so it would be readily understood how so light and powerful an engine as the Gnome had helped aviation. Many aeroplanes were built in the early days and fitted with so-called aeroplane engines, but most of them failed to fly until a Gnome was used.

There was, he said, a great scarcity, both in England and abroad, of really good aeroplane engines. At present most engines only made about 1,000 revs. per minute. Recently, some motor-car and cycle records had been broken by engines giving 1,000 revs. per minute and developing enormous power for their size. One might naturally suppose that the life of such an engine would be short, and that it would pull itself to pieces, but on the contrary, the opposite was the case, provided that the engine was well designed and well made. It was essential that the reciprocating parts be properly balanced. These high-speed engines ran with an even purr like a turbine, and there was a steadier and more uniform pressure in the cylinders. A propeller driven by an engine of such high speed would require gearing down to about 1,000 revs. per minute. This again was an advantage, as there were more explosions to each revolution of the propeller.

In the Gnome engine the cylinders revolved and acted as a flywheel, an arrangement which was found to be very effective on the whole, but it had its disadvantages, though this engine had proved and was proving enormously successful. There was no doubt that in the near future the engine with stationary cylinders would prove more successful, as this type was more economical to run, the cylinders were less liable to blow off, and should they do so, there was less likelihood of serious consequences.

Bleriot's flight across the Channel was perhaps one of the most sensational feats in aviation. It awakened the world to the possibilities of flight. Bleriot had specialised in monoplanes. He once built a biplane but did not try it. One might naturally ask, "Why make biplanes if monoplanes fly so well?" But as in everything else, it was a case of balancing up a number of advantages and disadvantages. The advantages of monoplanes were: (1) Slightly greater efficiency per square foot of surface; and (2) simplicity. The disadvantages were: (1) Aspect-ratio not so good as that obtained on the biplane or multiplane; (2) wings blotted out a wider range of vision; (3) angle of bracing more acute, which was not so effective. The advantages of biplanes were: (1) As the bracing angles were less acute and the load spread over a larger surface, a lighter construction could be employed; (2) good aspect-ratio could also be employed; (3) view better; (4) in the case of accident, the pilot and passenger were better protected, especially in the tractor type, *i.e.*, with the engine in front; and (5) rising and falling vertical wind pockets had less effect. The disadvantages were: Slightly more complicated, and not quite so efficient per square foot of surface. This inefficiency was due to the effect of the planes on one another, principally that the lower disturbed the air to the upper. This loss could be slightly obviated by "staggering" the planes, *i.e.*, placing the upper planes a little in advance of the lower. It was also reduced by making the distance of the planes apart about 1·2 of the chord.

In concluding his paper, the lecturer gave the comforting assurance that flying was becoming less risky each year. At first one aviator was killed for about every 500 miles flown. The mileage quickly rose to 5,000, then 50,000, and to-day there was about one person killed for about 100,000 miles flown.

A vote of thanks to the retiring president, Mr Charles Day, of Messrs. Mirrlees, Bickerton, & Day, Ltd., Stockport, concluded the proceedings.

Rolling Mill Speeds.—A lecture was delivered at a recent meeting of the Sheffield Society of Engineers and Metallurgists, by Mr. C. E. Larard, who dealt with the subject of "Phenomena of Elastic and Plastic Strains." The author gave much information as to the behaviour of steels under applied torsional stresses of increasing magnitude. With the aid of the cinematograph he showed these materials twisting up under the strains until they were eventually fractured, and the "flow" of the metal owing to the strain could be followed from the beginning of the test to the end. He expressed the opinion that the advantages of the cinematograph as an instrument of research had not yet been fully realised.

COMPARATIVE TESTS OF LOCOMOTIVE BOILERS

Fitted with Jacobs-Shupert and Radial Stay Fireboxes.

For the purpose of determining the relative merits of the Jacobs-Shupert form of firebox as compared with one of the ordinary radial stay design, a series of tests were undertaken by Prof. W. F. M. Goss, the results of which have recently been published in the form of an exhaustive report, issued by The Jacobs-Shupert United States Firebox Company, Coatesville, Penn., U.S.A. For the purpose of the tests two boilers were employed of precisely the same dimensions, and differing only in the style of the firebox—one being fitted with the Jacobs-Shupert, and the other with the radial stay firebox. These are shown in the accompanying sectional views, Figs. 1 and 2, the dimensions being as follows:

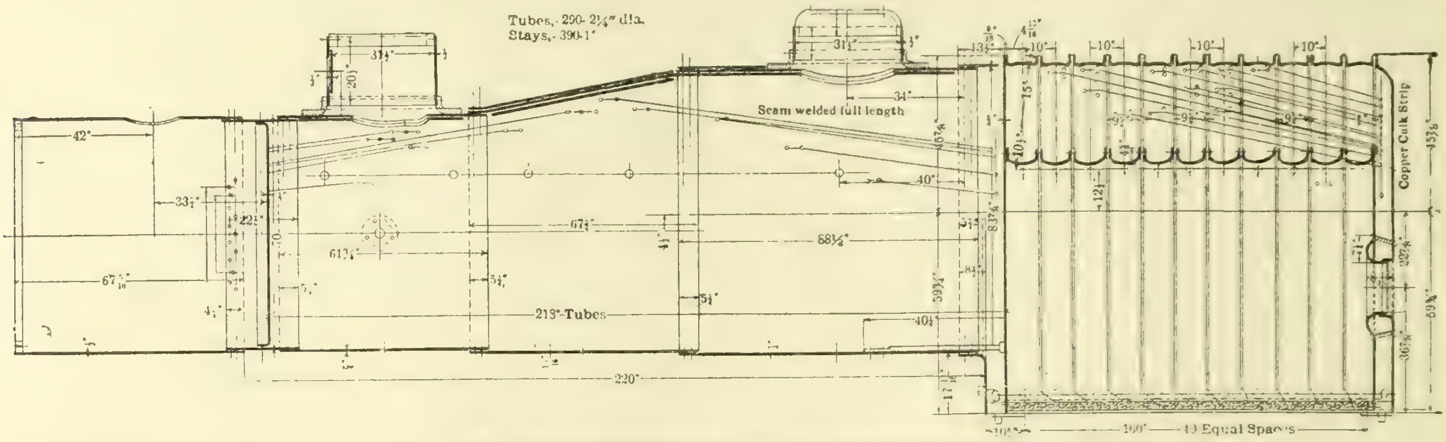


Fig. 1.—Longitudinal Section of Jacobs-Shupert Boiler.

	Jacobs-Shupert.	Radial Stay.
Type of boiler	Extended wagon top	Extended wagon top
Diameter of shell	70in.	70in.
Number of 2¼in. tubes	290	290
Length of tubes	18ft. 2in.	18ft. 2in.
Length of firebox	9ft. 1⅞in.	9ft. 1$\frac{11}{16}$in.
Width of firebox	6ft. 4⅞in.	6ft. 4¾in.
Grate area	58·14 sq. ft.	58·07 sq. ft.
Heating surface—		
Firebox	230·8 sq. ft.	206·7 sq. ft.
Tubes	2,759·0 sq. ft.	2,759·0 sq. ft.
Total	3,008·4 sq. ft.	2,984·3 sq. ft.
Distribution of heating surface in tests, Series A—		
Firebox end	201·9 sq. ft.	179·2 sq. ft.
Barrel end	2,806·5 sq. ft.	2,805·1 sq. ft.

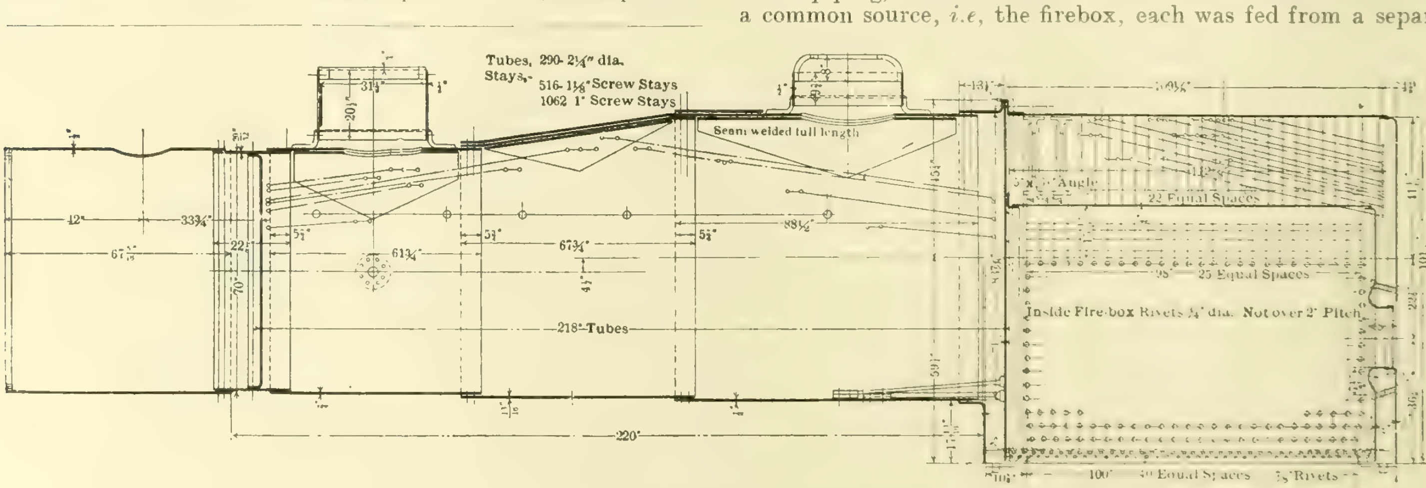


Fig. 2.—Longitudinal Section of Radial Stay Boiler.

The tests were divided into three groups designated as series "A," series "B," and series "C," respectively. Tests "A" were made to ascertain the relative amount of heat absorbed by the fireboxes, and by the tubes of the two boilers under similar operating conditions. To enable these tests to be undertaken the boilers were each constructed with a partition separating the water space into two compartments, one of which included the firebox surface and the other the tube surface. In carrying out the tests, these compartments were separately fed with weighed water. In addition to establishing the relative value of a unit area of firebox heating surface as compared with that of a unit area of tube heating surface, these tests were meant to disclose the difference, if any, in the heat absorbing capacities of the two fireboxes tested.

The regular flue sheet was employed in the test series "B," which necessitated the removal of the partitions. These tests were made for the purpose of establishing the evaporative efficiency and capacity of each boiler, under different rates of power. Advantage was also taken of the opportunity to obtain information concerning the circulation of water within the two boilers.

Series "C" comprised low water tests of both boilers. Some particulars and illustrations relating to these tests appeared in our issue of July 19th last, see p. 79, Vol. XXX.

A temporary laboratory was constructed for making the tests series "A" and "B," in which the two boilers were arranged side by side and each equipped for testing independently of the other. Fig. 3 shows the testing equipment of the Jacobs-Shupert boiler, the same arrangement being employed for the radial stay boiler. The arrangement of the boilers it will be seen from Fig. 3 were such as to accord as closely as possible to ordinary service conditions. The boilers and steam piping were well lapped with asbestos.

Tests Series "A."

Relative Value of Firebox and Tube Heating Surface.—The firebox ends of the boilers were partitioned off from the barrel ends as indicated above. The two compartments in each boiler were connected only through the medium of the steam piping, and while both in each case received heat from a common source, *i.e*, the firebox, each was fed from a separate supply of weighed water, and the output of steam from each end was dealt with as though coming from separate boilers. The location of the partitions were such as to cause the heat transmitted through the back tube sheet to be effective in producing evaporation in the barrel ends of the boilers. While in the observed data the actual quantities of water fed to each end of each boiler are recorded, a correction has been applied in the reduced values whereby the fire-

box is credited with as much greater evaporation as the rear tube sheet surface added to the remaining firebox heating surface represents an increase in the total; this quantity being deducted from the evaporation otherwise credited to the barrel ends of the boilers.

In the operation of the boilers constructed and equipped as described, a series of conditions appeared which, while unexpected, were interesting. It was found after starting fires under cold boilers that the firebox ends of the boiler would begin to make steam, while the barrel remained comparatively cold. The steam thus generated by the firebox passed through the piping to the cooler steam space of the barrel, where much of it condensed. As a result, the water level of the barrel would gradually rise and the water level in the firebox end would fall. The progress of these changes soon made it necessary to blow off water from the barrel and to feed water to the firebox end. This action operated greatly to prolong the process of getting the boiler into action. After the barrel began to make steam both compartments performed normally, as two boilers of a single battery, the quality of steam delivered from each being practically of the same value. It is obvious that the action described has nothing to do with the differences in the design of the two boilers, but was a result of the manner in which they were fitted up for the test in hand. The action occurred in connection with both boilers. It was completely overcome by adding a 2in. emergency pipe connecting a washout hole in the bottom of the barrel with a washout hole in the water leg of the firebox. This connection permitted, during the process of warming up, the firebox end to be supplied with water

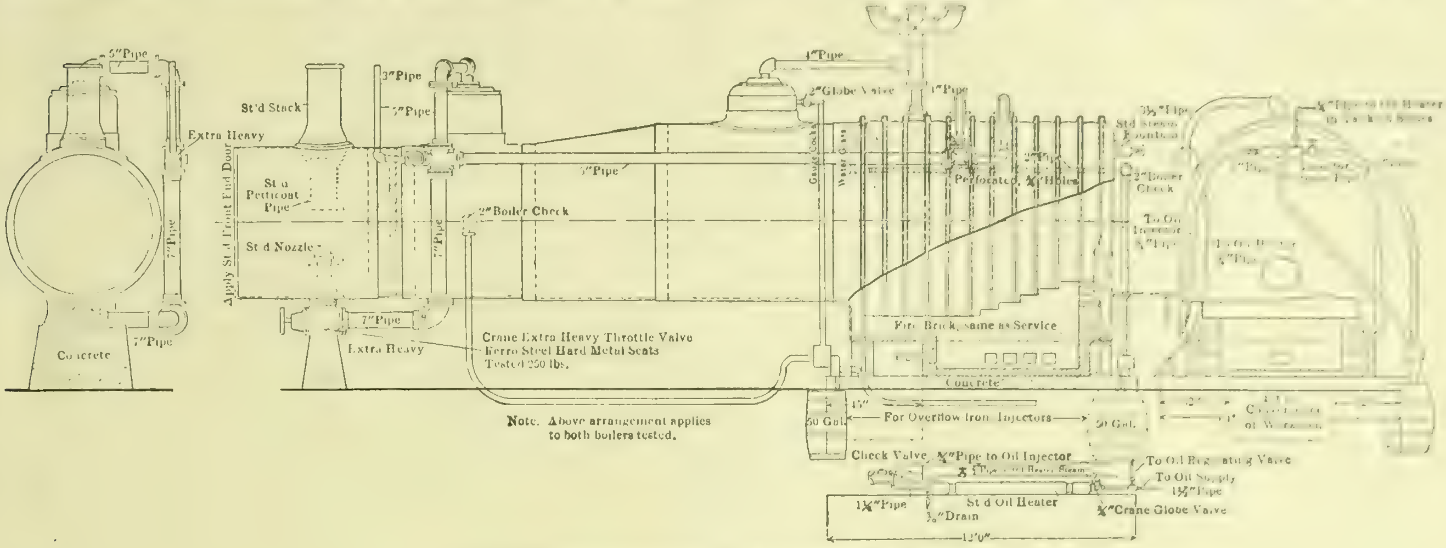


FIG. 3.—PIPING ARRANGEMENT FOR BOILERS, AS TESTED.

TABLE I.

Designation of Test.	Draught in Front of Diaphragm Inches of Water.	Oil per Hour pounds.	Equivalent Evaporation per Hour. Firebox pounds.	Equivalent Evaporation per Hour. Barrel pounds.	Equivalent Evaporation per Hour. Total pounds.	Equivalent Evaporation per Square Foot of Heating Surface per Hour. Firebox pounds.	Equivalent Evaporation per Square Foot of Heating Surface per Hour. Barrel pounds.	Equivalent Evaporation per Square Foot of Heating Surface per Hour. Total pounds.	Per Cent. of Total Evaporation in Firebox.	Equivalent Evaporation per lb. of Fuel pounds.	Efficiency (over all) per Cent. of B.Th.U. Absorbed by the Boiler Per lb. of Fuel Fired.
A-1-J	1·5	736	6,136	5,604	11,740	26·59	2·02	3·90	52·27	15·96	80·48
A-2-J	2·6	1,453	10,428	11,509	21,937	45·18	4·14	7·29	47·54	15·10	76·35
A-3-J	3·0	1,399	9,227	11,650	20,877	39·98	4·19	6·94	44·27	14·92	75·44
A-4-J	5·2	2,156	11,683	18,186	29,869	50·62	6·55	9·93	39·11	13·86	70·05
A-5-J	6·5	2,117	11,206	17,750	28,956	48·55	6·39	9·63	38·70	13·68	69·15
A-6-R	1·2	790	6,914	5,546	12,460	33·45	2·00	4·18	55·48	15·77	79·72
A-7-R	2·8	1,504	9,743	12,141	21,884	47·14	4·37	7·33	44·52	14·55	73·55
A-8-R	2·6	1,440	10,946	10,734	21,680	52·96	3·86	7·27	50·49	15·06	76·14
A-9-R	6·1	2,106	11,942	15,847	27,789	57·78	5·71	9·31	42·97	13·20	66·70

TABLE II.

Designation of Test.	Draught in Front of Diaphragm Inches of Water.	Kind of Coal.	Moisture Free Coal Fired per Hour pounds.	Equivalent Evaporation per Hour. Firebox pounds.	Equivalent Evaporation per Hour. Barrel pounds.	Equivalent Evaporation per Hour. Total pounds.	Equivalent Evaporation per Square Foot of Heating Surface per Hour. Firebox pounds.	Equivalent Evaporation per Square Foot of Heating Surface per Hour. Barrel pounds.	Equivalent Evaporation per Square Foot of Heating Surface per Hour. Total pounds.	Per Cent. of Total Evaporation in Firebox.	Equivalent Evaporation per lb. of Moisture Free Coal as Fired pounds.	Efficiency (over all) per Cent. of B.Th.U. Absorbed by the Boiler Per lb. of Fuel Fired.
A-101-J	1·2	Scalp Level	1,324	6,149	8,363	14,514	26·61	3·01	4·82	42·36	10·96	71·62
A-102-J	1·3	Dundon	1,622	6,944	7,306	14,250	30·09	2·63	4·74	48·74	8·79	62·01
A-103-J	4·4	Scalp Level	2,498	8,949	16,379	25,328	38·77	5·90	8·42	35·33	10·14	66·79
A-104-J	4·2	Dundon	2,990	9,826	15,853	25,679	42·57	5·71	8·54	38·27	[illegible]	67·30
A-105-J	7·3	Dundon	4,228	11,982	23,423	35,405	51·92	8·43	11·77	33·84	8·38	58·65
A-106-J	6·7	Dundon	4,392	12,043	22,340	34,383	52·18	8·04	11·43	35·03	7·83	55·12
A-107-R	1·5	Dundon	1,721	7,225	7,538	14,763	34·95	2·71	4·95	48·93	8·58	60·22
A-108-R	1·1	Scalp Level	1,434	6,383	8,620	15,003	30·88	3·10	5·03	42·54	10·46	68·65
A-109-R	3·4	Scalp Level	2,418	7,734	16,427	24,161	37·42	5·91	8·10	32·01	9·90	64·68
A-110-R	3·1	Dundon	2,835	9,848	14,589	24,437	47·64	5·25	8·19	40·30	8·62	60·51
A-111-R	7·7	Dundon	4,250	11,992	23,782	35,774	58·02	8·56	11·99	33·52	8·42	61·10
A-112-R	6·4	Dundon	4,138	11,009	23,544	34,553	53·26	8·48	11·58	31·86	8·35	60·09

from the barrel end, and it established a channel for circulation which was found to be necessary to normal action. The pipe in question was provided with two valves and a drain between so that the circulation could be effectually stopped after both parts of the boiler were gotten into action.

Results of Tests, Series "A," Oil as Fuel.—Numerical values which are of especial interest in connection with this series of tests are presented in Table I., and a diagram showing the percentage of the total heat absorbed by the firebox in Fig. 4. The points plotted in this diagram include all results as obtained from both the Jacobs-Shupert boiler and the radial stay boiler. Referring to Table I., it will be seen that

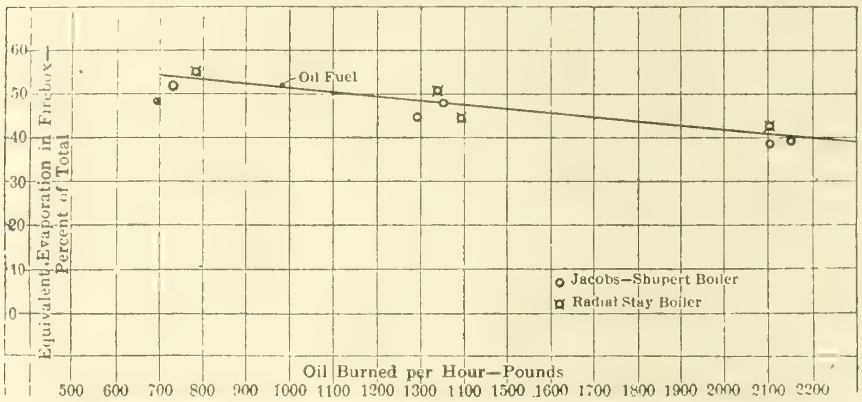


FIG. 4.—RATIO OF EVAPORATION IN FIREBOX TO OIL BURNED PER HOUR.

each pound of oil burned resulted in the evaporation of from 15·9lbs. to 13·2lbs. of water, the amount diminishing as the rate of power is increased. The thermal efficiency of the Jacobs-Shupert boiler under low rates of power may exceed 80 per cent., and even under high rates of power it is above 70 per cent. It appears that when the Jacobs-Shupert boiler is made to evaporate 20,000lbs. of water an hour, it will generate 14·14lbs. of steam for each pound of oil burned; also, from the coal tests, that at the same rate of power, it will generate 8·3lbs. of steam for each pound of Dundon coal burned, so that a comparison of the results of the coal and oil tests indicates that 1lb. of oil in locomotive service is equal to 1·7lbs. of high-grade bituminous coal

With reference to the distribution of work between the firebox and the tubes, Fig. 4 shows that the fraction of the total heat transmitted which is taken up by the firebox is greatest when the rate of power is low. Thus when only 800lbs. of oil are being fired per hour, 54 per cent. of the total evaporation is from the firebox surface, whereas when 2,200lbs. of oil are fired per hour, 40 per cent. of the total transmission is through the firebox. This statement shows that the proportion of the whole work done by the firebox is not only surprisingly large at its maximum, but that it continues to be large under all conditions of operation. Translating the facts presented by these values given into measures which are more readily recognised, and expressing them in round numbers, it may be said that when served with 2,200lbs. of oil per hour, the Jacobs-Shupert boiler will evaporate 40,000lbs. of water per hour. Of this amount 16,000lbs. will be evaporated by the firebox and 24,000lbs. by the barrel; the whole boiler will develop 1,200 h.p., of which amount nearly 500 h.p. will be developed by the firebox; the average rate of evaporation per foot of heating surface per hour for the whole boiler will be 9·78lbs.; the average rate of evaporation per foot of heating surface per hour for the firebox will be 49·59lbs., and for the barrel 6·47lbs.; and the ratio of heat absorbed per foot of tube heating surface is as 7·6 to 1.

While the tests show the efficiency of the boilers when fired with oil to be high, and while the results are very consistent, they cannot be accepted as constituting a basis of comparison which admits of a high degree of refinement. This fact arises from difficulties encountered in the maintenance of a satisfactory fire. The burning of oil in large quantities within the firebox of a locomotive boiler presents a problem which has not yet been perfectly solved. In the case of the boilers experimented upon, the burner, the brickwork, and all other provisions affecting combustion were made to agree with the practice of large railway corporations having hundreds of locomotives oil-fired. It is believed that the results obtained at the testing plant were probably as satisfactory as any which are obtained upon the road, but it was impossible in the maintenance of the fire to prevent deposits of soot upon the heating surface.

The practice of thoroughly cleaning the heating surfaces before starting fires, and of afterwards doing nothing to them during the progress of the test, resulted in abnormally high smoke-box temperatures and in the accumulation of considerable quantities of soot, which was required to be removed at the end of the test. All results obtained under this practice were finally discarded. Later recourse was had to sanding the tubes, a practice common on railroads. At regular intervals during the progress of the test a scoopful of sharp sand was carefully distributed through the door into various portions of the furnace in such a manner that the particles would be taken up by the draught and carried through the tubes, cleaning them as by a sand-blast process. While this practice gave cleaner tubes, it did not clean the firebox, and an attempt was made to reach this portion of the heating surface by using an air-blast with sand.

As a result of these efforts systematically applied, the results obtained are fairly consistent, but since it is known that the performance of the boiler was more or less affected by the presence of soot, and since it can never be certain that the extent of this defect was constant for all the tests made of record, the results cannot be accepted as constituting a measure of the relative performance of the two fireboxes, which is satisfactory from a scientific point of view. For this reason, also, no attempt was made to elaborate, through a complete heat balance, the computations of the oil-fired tests.

Results of Tests, Series "A," Coal as Fuel.—The more essential facts developed by these tests are set forth in Table II. This table includes the results of twelve tests, six upon the Jacobs-Shupert boiler and six upon the radial stay boiler. For each boiler two tests were made with Scalp-Level coal and four with Dundon coal. The Scalp-Level coal burns with a short flame. Its analysis (coal as fired) is as follows:—

	Per cent.
Fixed carbon	75·90
Volatile matter	16·45
Moisture	2·15
Ash	3·50

The Dundon coal is a long-flame gas coal. Its analysis (coal as fired) is as follows:—

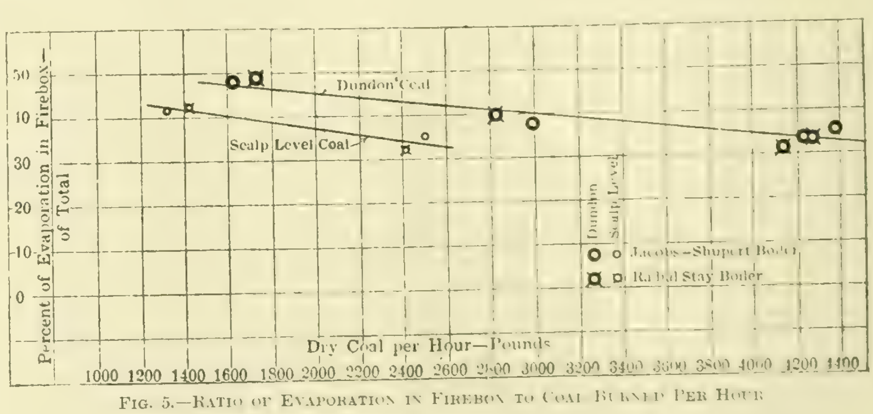


FIG. 5.—RATIO OF EVAPORATION IN FIREBOX TO COAL BURNED PER HOUR.

	Per cent.
Fixed carbon	49·54
Volatile matter	34·34
Moisture	3·38
Ash	12·74

The results show that under low rates of power either

boiler will give an evaporation of more than 10lbs. of water per pound of coal. For the whole series of tests the evaporation is normally above 8lbs. of water per pound of coal. A comparison of the performance of the whole boiler when delivering a definite amount of power, shows that the thermal efficiency is from 8 to 10 per cent. less when coal is fired than when oil is used as fuel.

The percentage of the total heat absorbed by the boiler, which is taken up by the firebox when the fuel is coal, is shown diagrammatically by Fig. 5. The points plotted upon this diagram fall into two series of groups. The first located by heavy circles represents all results obtained with Dundon coal, both from the Jacobs-Shupert boiler and the radial-stay boiler. The second, located by smaller circles, represents results obtained with the Scalp-Level coal. Neither boiler was equipped with the brick arch during these tests. It is interesting to note that the short-flame coal is at a distinct disadvantage as compared with the long-flame coal in giving up heat to the firebox. When Dundon coal is used as fuel, the percentage of the total heat absorbed by the firebox varies from a little less than 50 to a little more than 30, depending upon the rate of power, the percentage diminishing as the power is increased. When Scalp-Level coal is used the percentage is about 8 less than when Dundon coal is used.

If it be assumed that the Jacobs-Shupert boiler evaporates 20,000lbs. of water per hour, the percentage of the total heat absorbed by the boiler, which is taken up by the firebox, is as follows:—

	Per cent.
When oil is used as fuel	42
When long-flame bituminous coal is used as fuel	42
When short-flame coal is used as fuel	35

This has suggested the possibility of the existence of some relation between the percentage of total heat which is absorbed by the firebox and the character of the fuel. For example, it is thought possible that the substitution of anthracite for bituminous coal would operate to reduce the total work done by the firebox below 35 per cent. The explanation is perhaps due to a changed condition in the tubes rather than in the firebox. It may be that the freer burning coal deposits less soot in the tubes and permits them to absorb a larger proportion of the total heat delivered.

It will be of interest to note that with Dundon coal when the rate of combustion equals 4,341lbs. per hour, which is near the highest reached in firing the partitioned boilers, the Jacobs-Shupert boiler will evaporate 35,405lbs. of water per hour, of which amount 11,982lbs. will be evaporated from the firebox and 23,423lbs. from the tubes; the whole boiler will develop 1,026 h.p., of which amount 304 h.p. will be developed by the firebox; the average rate of evaporation per foot of heating surface per hour for the whole boiler will be 11·77lbs.; the average rate of evaporation per foot of heating surface per hour for the firebox will be 51·92lbs., and for the barrel 8·43lbs.; and the rate of heat absorbed per foot of heating surface by the firebox to that absorbed per foot of tube heating surface is as 6·15 to 1.

Comparison of the Performance of the Two Fireboxes.—The Jacobs-Shupert firebox and the radial-stay firebox were designed and constructed to have the same over-all dimensions. The heating surface of both fireboxes, as measured by their projected areas, is substantially the same and is equal to 206·7ft. The curved form of the sections of the Jacobs-Shupert firebox, however, gives a developed area which is greater than that of the plain surface of the radial stay firebox. The developed area of the surface of the Jacobs-Shupert firebox is 230·8ft., an increase over the surface of the radial-stay firebox of 11 per cent. This increase in the heating surface of the Jacobs-Shupert firebox is an incident in the development of its design. The purpose of giving the sections of the firebox the shape they have was not primarily that greater heating surface may be secured, but that a satisfactory structure might result. Nevertheless, a question as to the effect of this increase in heating surface upon the amount of heat absorbed by the firebox, is one of some importance, and its determination constitutes one of the questions for which this series of tests was instituted. The results upon this point, as briefly reviewed in Tables I. and II., are not conclusive.

While results of individual tests may be selected which will show a considerably higher percentage of the total heat absorbed to have been taken up by the Jacobs-Shupert firebox than by the radial-stay firebox, their effect is neutralised by the possibility of other comparisons involving results believed to be equally reliable. The fact as developed by the results of 20 tests seems to indicate that the difference in absorbing capacity of the two fireboxes tested is not sufficient to be established by carefully conducted boiler tests. Heat transmitted by a locomotive firebox is chiefly the result of conduction and convection; radiation probably plays but a small part. Transmission by conduction is a function of differences in temperature. If in the case in hand, a plane in the water space above the crown-sheet is considered as receiving the heat, and a parallel plane in the firebox below the crown-sheet as the source of heat supply, the amount of heat transmitted will theoretically be independent of the form of the metallic crown-sheet between. Again, the convection currents have a clear sweep over certain exposed portions of the firebox sections, but do not reach other portions which are between the sections. It is not unlikely that considerations such as these account for the results which have been obtained.

(To be continued.)

SCHMIDT'S STEAM ENGINE CYLINDER.

A DESIGN of cylinder for steam engines, the invention of M. Schmidt, Hirschberg, Silesia, Germany, is shown in the accompanying sectional views. In this design the cylinder heads A and B are hollow, in order that they may be heated by means of steam. The chamber of the back head A is provided with an admission port C, through which the live steam enters. From the chamber of the back head A the steam flows to the back distributing valve D, which, like the front valve E, is operated by suitable mechanism not shown. A pipe F leads from this back valve D to the chamber in the front head B. This chamber is in communication with the casing of the front distributing valve E. The steam therefore

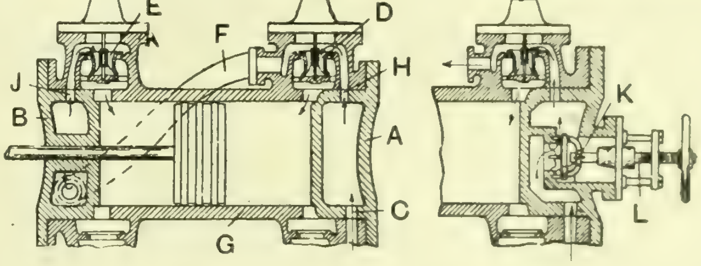


FIG. 1. FIG. 2.
SCHMIDT'S STEAM ENGINE CYLINDER.

follows successively through the back head, back valve, connecting pipe, front head and front valve. In this way the two heads of the steam cylinder are heated by the current of live steam, and the front one, which receives the steam last, is heated somewhat less than the back one, which, it is claimed, is advantageous because a smaller amount of heat is transmitted to the frame of the engine which is connected with the front head. Further, only one steam admission pipe is necessary and it is not necessary to have a forked pipe, whereby space and expense are saved. The stop valve may also easily be constructed in the chamber in the back head A, as shown in Fig. 2, so that its spindle L lies in the axis of the cylinder and projects towards the rear from the head.

Explosion on a French Submarine.—While the French submarine "Foucaulty" was undergoing trials off Cherbourg during the past week her engine exploded after working satisfactorily for two hours. Seven men were injured, two seriously.

Lift Accident.—A serious lift accident occurred recently on the premises of the English Record Company, Tottenham Court Road, London. Five persons were injured, and were taken to the Middlesex Hospital. The lift was used for goods, and a number of people made use of it on returning from lunch. The cable snapped while the lift was in motion, and it fell some distance to the bottom.

THE CORROSION OF DISTILLING CONDENSER TUBES.*

BY ARNOLD PHILIP, B.SC., A.M.I.E.E., A.R.S.M.
(ADMIRALTY CHEMIST.)

DISTILLING apparatus is largely used both on merchant steamers and on ships of the Royal Navy for the purpose of preparing fresh water, not only for washing and cooking purposes, but also for supplying the make-up feed water for the steam boilers. The distilling apparatus consists in general of two parts. Firstly, a cylindrical boiler or evaporator which is fed with sea water either by hand or automatically. In this sea water a steam heating coil is either partially or totally immersed. Through this steam heating coil a current of high-pressure boiler steam (primary steam) is passed at a temperature of from 240° to nearly 400° Fah. The raising of the sea water surrounding the coils to this temperature causes it to boil, and the steam (known as secondary steam) which is thus evolved from it passes over into the second part of the distilling plant. This is known as the distilling condenser, and is in general very similar in construction to the forms of main and auxiliary condensers used on steamships.

There are, however, one or two differences between the construction of the distilling condenser and the auxiliary and main condensers as now generally used in H.M. service which should be noted. In the distilling condenser the steam passes through the condenser tubes and the cooling water circulates outside them. This is the reverse of the usual practice in main and auxiliary condensers. Secondly, the tubes in the distilling condenser are usually vertical and expanded into the tube plates, whilst in the main and auxiliary condensers they are horizontal and pass through watertight glands in the tube plates.†

It is interesting to remark here that, whether on account of the fact that the distilling condenser tubes are vertical, or whether because they are expanded at their ends into metallic contact with the tube plates, or whether because the sea water circulates outside the tubes inside a steel casing instead of inside the tubes, no case is known to the author of corrosion trouble occurring to the tubes in these condensers on their sea-water side. This statement that corrosion is absent on the sea-water side of condenser tubes in a distilling condenser merely represents the author's personal experience and the results of the enquiries he has been able to make, and to this extent it appears to confirm the views already expressed by him in previous communications to the effect that by far the greater part of the trouble with the corrosion of condenser tubes with sea water is due to the presence of carbon or other electrically conducting relatively electro-negative body deposited along the inside of the tubes at the bottom, and that on the other hand practically all the other less important corrosive actions can be stopped by the use of masses of properly connected iron and steel or perhaps aluminium and zinc as protective metals.

Notwithstanding this freedom from corrosion of the tubes of distilling condensers upon their outer or sea-water surfaces, very great difficulties have been experienced from the corrosion of these tubes upon their inner or steam surfaces. From time to time in the past, what in the aggregate is a large number of cases have occurred in which very serious corrosion has taken place on the steam side of the condenser tubes of sea-water distilling apparatus. The trouble usually first made its appearance by the presence of what was believed to be priming in the distilling evaporator. This was indicated by the fact that the water from the distilling condenser gave a precipitate or cloudiness when tested with silver nitrate solution. More marked symptoms of corrosive action were indicated by the distilled water possessing a disagreeably metallic taste, and reports from various ships showed that soap used with such water sometimes gave a light bluish-green curd. In one case the distilled water, after boiling in the ship's "copper," was used for making tea, and gave a black coloured infusion, whilst the ship's "copper" (actually made of iron) became coated internally with metallic copper. In short the distilled water contained copper, and on examining the distilling condenser tubes they were found to be markedly corroded on their steam side. The corrosion was so active that the distilled water in once passing through the tubes dissolved sufficient copper from them to produce the troubles referred to. The cause of the presence of the copper was at first, as stated above, attributed to the priming of the sea water in the evaporators, and the action of the sea salt thus passing over into the distilling condenser tubes was looked upon as causing the solution of the copper. This view appeared to be confirmed by the fact that the usual silver nitrate test of the distilled water seemed always to demonstrate the presence of salt.

Early endeavours to reduce the effects of the supposed priming were made by coating the insides of all the condenser tubes and other steam pipes with tin, whilst steel and zinc vapour baffle plates and protector blocks were placed in the head of the evaporator and in the vapour pipe connecting the head of the evaporator with the distilling condenser. Both these remedies were found to effect a temporary cure, but unfortunately after a while the same troubles reappeared. The degree to which these difficulties, due to the corrosion of the tubes and the presence of copper in the distilled water, were noticed was found to vary a good deal in different ships, and even in the same ship marked fluctuation occurred from time to time.

The author's first examination of a case in which corrosion of distilling condenser tubes had been observed was in August, 1904, and on looking through previous correspondence upon this and other similar corrosions he found, in a letter written by an engineer officer in 1903, the suggestion that as part of the heating surface of the primary steam coils in a particular evaporator was under normal conditions of working left above the sea-water level, it was possible that this getting quickly coated with scale and consequently overheated might evolve hydrochloric acid from the magnesium salts found in the deposit, and that it was the acid thus evolved which caused the corrosion observed in the distilling condensers.

This observation appeared to be a very probable explanation of the corrosive troubles which had been noticed, and steps were at once taken to fully examine the particular case then under question from this point of view. It was found that generally evaporators may be divided into two classes, namely, those containing drowned heating coils (*i.e.*, in which the primary steam coils are completely immersed in the sea water or brine which they are used for heating), and those in which the primary steam coils are only partially covered with water.

Experiments made on board a ship which was fitted with evaporators both of the drowned coil type and the partially exposed coil type showed that when connected to the distilling condenser the drowned coil type evaporator always made water practically quite free from copper, whilst the evaporator with the exposed heating coils when connected to the same condenser gave water which contained copper. The brine from both types of evaporator was then examined, and it was found that from the drowned coil type it had a very faintly alkaline reaction to phenolphthalein, whilst the brine from the evaporator having the partially exposed heating coil possessed a very strongly alkaline reaction to the same indicator.

On opening up an evaporator and examining the inside surfaces of the walls of its casing, it is usually found that the lower portion, which contains the sea water or brine which is undergoing evaporation, is coated all over with a brilliant white incrustation, and this white incrustation extends upwards above the level of the brine, as far, in fact, as the water can splash when boiling. Above this region, however, the inside surfaces of the head of the evaporator (if it is not of the drowned coil variety) are usually much corroded and coloured a deep orange-brown. The tops of the steam coil, as far as they project above the surface of the brine, are also thickly coated with white incrustation. Chemical analysis shows this incrustation to be a mixture of calcium

* Paper read before the Institute of Metals, March, 1913.

†It should be stated that distilling condensers of other patterns in which the cooling water passes through the tubes and also in which the tubes are horizontal are used, but the type most generally employed until recently is that here described, and the remarks as to corrosion on the sea-water side of distilling condenser tubes must be understood to apply to this form of condenser only.

sulphate and basic sulphate and chlorides of magnesia, together with a considerable proportion (2·35 per cent.) of magnesium hydrate. This incrustation is normally heated up to practically the same temperature as that of the primary steam, *i.e.*, to a temperature considerably over that of the boiling brine, and it is at the same time constantly splashed with the boiling brine itself. Under these conditions the magnesium chloride present is decomposed, hydrochloric acid is evolved with the steam, and a strongly alkaline incrustation and also an alkaline brine are formed.

The chemical tests on the white incrustation and the alkalinity of the brine itself clearly show that some acid must have been driven off by the process of treating the sea water in the evaporator. Sea water is itself quite neutral to phenolphthalein to commence with, and the amount of alkaline base found to be separated was much greater than could be explained by any other hypothesis than that hydrochloric acid had been driven off.

In order, however, to demonstrate beyond dispute that hydrochloric acid was actually evolved, it was considered desirable to prove its presence in the distilled water. This was a matter of some little difficulty, on account of the very small amount in which the acid was present, namely, from 0·1 to 0·05 or less parts of HCl per 100,000. To determine the acidity of such a weak solution by direct titration is not a satisfactory procedure. Hydrochloric acid is so volatile that it is not possible to concentrate it by evaporation. The distilled water, besides containing hydrochloric acid, also contains sodium chloride due to slight priming, and also chlorides of copper, tin, and zinc, formed by the acid water flowing through the condenser tubes. The quantities of these metallic chlorides which are present in the water are of about the same order of magnitude as the amount of hydrochloric acid itself. As these salts lose HCl on evaporating to dryness, the method of determining the difference between the total chlorine present in the water and then the chlorine present in the solid residue after distillation to dryness does not give the correct amount of free hydrochloric acid present.

The method of test which was finally adopted was to add sufficient of a saturated solution of pure sulphate of silver (7·72 grams per litre) to the water. This causes a precipitate of silver chloride to be formed, and free sulphuric acid equivalent to the amount of free hydrochloric acid present is liberated; after heating to coagulate any silver chloride formed, it is filtered off and a large bulk of the water thus treated is evaporated down to a small bulk. This then contains all the free sulphuric acid. To demonstrate that it was free sulphuric acid a portion of it was dropped on a piece of lump sugar, and this was heated for an hour in a water oven at 210° Fah. The presence of the sulphuric acid was demonstrated by the blackening of the sugar as the acid became concentrated, whilst a similar piece of sugar treated as a control with a residue from ordinary distilled water to which the same amount of the silver sulphate solution had been added gave no blackening. In order to be certain that the silver sulphate was itself quite free from acid before use it was washed by boiling up with successive small quantities of distilled water, and the washed salt was employed for making up the silver sulphate solution used in the experiments. The actual determination of the amount of the free acid present was carried out by a titration on the concentrated residue, obtained from a further portion of the water under examination, after it had been treated with the pure silver sulphate solution as described above.

Tests carried out in this manner showed that the water obtained from distilling plant which caused corrosion of the condenser tubes, and which contained copper, invariably also contained free hydrochloric acid. The amount of copper present in such waters is conveniently estimated by a calorimetric test, using potassium ferrocyanide in comparison with standard solutions of a copper salt.

The results of some actual tests made upon samples of water obtained from two distilling plants, in which one had an evaporator with the upper portion of its primary steam coils above the surface of the boiling brine, whilst the other had its steam coils drowned (that is to say, completely immersed beneath the surface of the brine), are here given:—

Type of Evaporator.	Coils exposed above the Surface of the Brine.		Drowned Coils.	
Rate of working evaporator in tons of distilled water per diem.	16 tons	8 tons	13 tons	5 tons
Pressure of primary steam in lbs. per square inch absolute.......	215lbs.	60lbs.	40lbs.	25lbs.
Corresponding temperature of primary steam.	337·4 Fah.	292·5 Fah.	267·1 Fah.	240 Fah.
Pressure of secondary steam in lbs. per square inch absolute.......	30lbs.	27lbs.	18lbs.	15·5lbs.
Corresponding temperature of secondary steam.	258 Fah.	244·1 Fah.	221·9 Fah.	214·5 Fah.
Copper in grains per gallon present in the distilled water obtained. ..	0·32	0·56	0.005	0.008
Reaction of the brine in evaporating to phenolphthalein.	Strongly alkaline.	Strongly alkaline.	Very faintly alkaline.	Very faintly alkaline.
Reaction of distilled water to methyl orange.	Faintly acid.	Faintly acid.	Faintly acid.	Faintly acid.

At the date at which these results were obtained, 1904, the method of determining quantitatively the amount of free hydrochloric acid present had not been worked out, but tests for free hydrochloric acid made upon other samples of distilled water by the silver sulphate method a few months later showed, as has been stated above, that this acid in the free state is always present in the distilled water obtained from an evaporator in which the primary steam coils are exposed in the secondary steam space above the brine.

From the results given above, however, it is apparent that the rate at which an evaporator is worked, or, in other words, the temperature of the primary steam, caused the amount of copper in the distilled water, and therefore of the hydrochloric acid formed in the evaporator, to vary. The more the evaporator is pressed, the greater the amount of hydrochloric acid formed in a given time. There is further some evidence to show that the evolution of hydrochloric acid from the salts in sea water may not only be caused by the heating of the saline incrustation on the heated steam coils, but that this acid may also, but to a much smaller extent, be given off from the incrustations formed on the lower sides of the evaporator shell, and also possibly even from the brine itself, and in a given form of evaporator the formation of free hydrochloric acid is favoured by the high temperature of the primary steam coils and the strong concentration of the brine. To obtain the least quantity of hydrochloric acid from a given evaporator, it is therefore necessary to avoid too great a concentration of the brine by suitable adjustment of the sea-water feed and brine cocks, and also, and most effectively, to reduce the rate of evaporation as much as possible. Both of these methods of remedying the trouble are, however, faulty, for they both tend to render the evaporator inefficient. The best remedy is to only use evaporators with drowned steam coils.

The passage of copper into the boilers with the feed water is, of course, most undesirable from the point of view of boiler corrosion, and it has been proposed to avoid this by passing the distilled water through a scrubber of large granulated zinc or small zinc blocks. The feed tank into which the water from the distilling condensers is pumped is usually fitted with zinc protectors attached to its walls. In the absence of zinc scrubbers, if owing to defects in the evaporators the presence of copper in feed water is unavoidable, its harmful effects may be best minimised by keeping the water alkaline with lime, for this causes the objectionable soluble copper salt to be converted into the comparatively harmless insoluble precipitate of cupric hydrate, but this palliative with boilers running at high pressures, and in the presence of organic oils, must be regarded with distrust.

From what has been stated above, it is evident that the measure taken to prevent the presence of copper in the distilled water, by tinning the condenser tubes, causes the temporary disappearance of the copper, because tin instead of copper is dissolved from the inner surfaces of the condenser

tubes, and this metal is not readily detected in the distilled water, whilst directly the tin has been removed by the acid water the copper will once more make its appearance. The use of steel or zinc baffle plates in the head of the evaporator, and zinc protector blocks in the vapour pipe, also cause a temporary removal or diminution of the amount of copper in the distilled water, due to the fact that the baffles, &c., remove, or partly remove, the hydrochloric acid from the evaporator steam, but as the plates become rapidly corroded, they become inefficient and the trouble again appears.

The serious nature of the corrosion which may occur, due to the acid evaporator steam, is well shown from the following extract from a description by an engineer officer of what occurred in a ship using evaporators with steam coils which were not drowned: "The brass valves and valve seatings wear in the most excessive manner, in fact it appears as though one or more constituents of the metal were eaten out of it altogether, and only a hard mass left; this remark applies particularly to the vapour valves, through which the secondary (gained) steam passes. . . . It is no new thing, but has been going on for the past three years. The fresh water made always has a metallic taste, and when worked with soap turns a very slightly pale greenish colour; but the fresh water made by a second evaporator which has drowned coils is perfectly fresh, tasteless, and good, and gives no colour with soapy water, although the steam is condensed in the *same* distilling condenser as the unsatisfactory water from the other evaporator."

STRESSES IN STAYED CYLINDRICAL SHELLS.*

BY C. E. STROMEYER.

MAKERS of donkey boilers and similar vessels sometimes hope to increase the resisting power of the inner cylinders by securing them to the outer ones by means of stay bolts, but there is as yet no precise method of estimating the stresses which such an alteration will produce, and I have therefore attempted in the following brief enquiry to show how these estimates can be made. Imagine an annular space consisting of a small cylinder placed inside a larger one, with a number of holes drilled through both shells, and suppose that bars have been inserted into these holes, which bars are assumed to be perfectly free to move, and yet will not allow water to pass; then, on applying a pressure in the annular space, the two plates will separate from each other by an amount which can be estimated. If nuts are then screwed on to the ends of the stays, and these are subjected to tension stresses, the two shells will be drawn closer together, and the bolts will elongate. Clearly, the screwing up of the bolts has the same effect on the shells as reducing the internal pressure, so that in our enquiry we may split up the available pressure into two partial ones, one producing circumferential stresses and changes of diameters of the shells, the other producing tension stresses and elongations of the stays.

The subdivision of the available pressure into partial ones, of which each one produces definite stresses and changes of form, is the principle on which the following enquiry is based. It will be best understood by a reference to Figs. 1 and 2, in which the black lines A B represent part of the outer cylinder and C D part of the inner cylinder. In Fig. 1, let E F be part of a section of an imaginary shell interposed between the inner and outer shells, all the stays being severed, as shown. In Fig. 2 the stays are not severed, but the plates are cut up into rectangles; A B being equal to the circumferential pitch of stays in the outer shell, and C D the pitch in the inner shell. The vertical pitch between the rows of stays is h. Assume that the rectangular plates $h \times$ A B, and $h \times$ C D, are water-tight but frictionless fitting square pistons in the casing shown in Fig. 2, and that the stay is also a water-tight frictionless fit in a hole in the centre of the casing.

In Fig. 1, let r_2 and r_1 be the radii respectively of the outer and inner shells, then the length of the stays is $r_2 - r_1$. Let n be the number of stays in each circumferential row, then the angle α, Fig. 1, is $\left(\frac{2\pi}{n}\right)$ and the pitches A B and C D, Fig. 2, are respectively—

$$2 \cdot r_2 \cdot \sin\left(\frac{\pi}{n}\right) \text{ and } 2 \cdot r_1 \cdot \sin\left(\frac{\pi}{n}\right).$$

* Paper read at the spring meetings of the fifty-fourth session of the Institution of Naval Architects, March 14th, 1913.

The partial pressures p_1 and p_2 exist as shown in Fig. 1, and the partial pressures p_3 and p_4 exist as shown in Fig. 2. The two latter pressures are obviously related as follows:—

$$p_4 \times \text{A B} = p_3 \times \text{C D, or } \frac{p_4}{p_3} = \frac{r_1}{r_2},$$

otherwise the plates and stays would move in one direction or the other. Let t_2 and t_1 be respectively the thicknesses of plates of the outer and inner shells, and let a be the effective sectional area of the bolt stay; then if E is the modulus of elasticity, we have in Fig. 2 an increase of length $r_2 - r_1$ of stay bolt equal to—

$$\delta = \frac{p_1 (r_2 - r_1)\, h \,.\, 2 \,.\, r_2 \,.\, \sin}{\text{E} \,.\, a}\left(\frac{\pi}{n}\right)$$

$$= \frac{p_3 (r_2 - r_1)\, h \,.\, 2 \,.\, r_1 \,.\, \sin}{\text{E} \,.\, a}\left(\frac{\pi}{n}\right) = \delta_1 + \delta_2.$$

In Fig. 1, the increase of the radius r_2 is

$$\delta_2 = \frac{p_2 \,.\, (r_2)^2}{\text{E} \,.\, t_2},$$

and the decrease of the radius r_1 is—

$$\delta_1 = \frac{p_1\,(r_1)^2}{\text{E} \,.\, t_1}.$$

For $2 \,.\, \sin\left(\frac{\pi}{n}\right)$ write m = angular pitch of stays, which is nearly equal to α. In order to solve the above in terms of p_3, introduce values for—

$$p_4 = p_3 \frac{r_1}{r_2},\; p_1 = p - p_3,\; p_2 = p - p_4 = p - p_3 \frac{r_1}{r_2};$$

then—

$$\epsilon\, \delta = \epsilon\, (\delta_1 + \delta_2) = p_3\, (r_2 - r_1)\, \frac{m}{a} \,.\, h \,.\, r_1$$

$$= \left(p - p_3 \frac{r_1}{r_2}\right) a\, \frac{(r_2)^2}{t_2} + (p - p_3)\, a\, \frac{(r_1)^2}{t_1}$$

$$p_3 \,.\, r_1 \left[(r_2 - r_1)\, m \,.\, h + a\left(\frac{r_2}{t_2} + \frac{r_1}{t_1}\right)\right] = p \,.\, a\left(\frac{(r_2)^2}{t_2} + \frac{(r_1)^2}{t_1}\right)$$

$$p_3 = \frac{p\left(\frac{(r_2)^2}{t_2} + \frac{(r_1)^2}{t_1}\right)}{\frac{r_2 \,.\, r}{t_2} + \frac{(r_1)^2}{t_1} + \frac{r_1 \,.\, m \,.\, h}{a}(r_2 - r_1)}$$

Here $r_1 \,.\, m \,.\, h$ is the area of the portion of the inner plate which is supported by the stay bolt of the sectional area a.

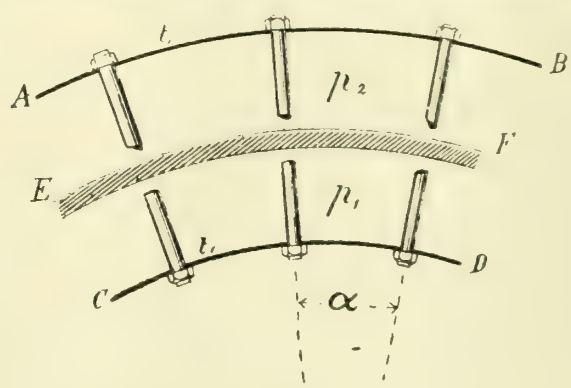


FIG. 1.

Having found p_3, the values of p_4, p_2, and p_1 are easily determined.

An annular superheater, of a type which was quite common in steamers about 30 years ago, may serve as an example. Height of superheater, 14ft. The respective diameters of the two cylinders are 72in. and 108in., so that $r_1 = 36$in. and $r_2 = 54$in. The two circumferences are held together by rows of bolt stays, pitched 14in. apart. Each row has 24 stays. Therefore—

$$m = 2 \sin\left(\frac{180^\circ}{24}\right) = 0{\cdot}261,$$

and the circumferential pitches in the outer and inner shells are respectively 14·1in. and 9·4in. The thicknesses of the plates of the outer and inner shells are ⅝in. and the bolt stays are 1⅛in. effective diameter, so that the effective area a is 1 sq. in.

Seeing that the inner cylinder, if 14ft. high and unstayed, would be permitted to work at a pressure of 35lbs. per square inch, and seeing that flat plates with stays pitched 14in. by 9·4in. as above, would be allowed a working pressure of 85lbs., it is probable that a stayed superheater of the above dimensions would be approved of for a working pressure of 35lbs. + 85lbs. = 120lbs. per square inch; unless the tube length be taken to be equal to the pitch of the rows of stays (14in.), under which supposition a pressure of 115lbs. + 85lbs. = 200lbs. per square inch might be permitted. It will here be assumed that $p = 120$lbs.; then, according to the above formula, the partial pressures are—

$p_3 \,.\, 36\,[18 \,.\, 0{\cdot}261 \,.\, 14 + 1 \,.\, (86{\cdot}4 + 57{\cdot}6)] = 120 \,.\, 1\,(4{,}666 + 2{,}073)$.

$p_3 = 120 \,.\, 6{,}739 : 7{,}533 = 120 \,.\, 0{\cdot}893 = 107{\cdot}1$lbs. per square inch.

$p_4 = p_3\, 36 : 54 = 107{\cdot}1 \,.\, \frac{2}{3} = 71{\cdot}4$lbs. per square inch.

$p_2 = p - p_4 = 120 - 71{\cdot}4 = 48{\cdot}6$lbs. per square inch.

$p_1 = p - p_3 = 120 - 107{\cdot}1 = 12{\cdot}9$lbs. per square inch.

The stress in the stay bolt is $S = p_3 \times 14 \times 9{\cdot}4 : 1 = 107{\cdot}1 \,.\, 131{\cdot}6 = 14{,}094$lbs., or 6·3 tons per square inch. The tension stress in the outer shell is $S_2 = 48{\cdot}6 \times 54 \times \frac{8}{5} = 4{,}199$lbs., or nearly 2 tons per square inch. The compression stress in the inner shell is $S_1 = 12{\cdot}9 \times 36 \times \frac{8}{5} = 743$lbs., or about $\frac{1}{3}$ ton per square inch.

It will thus be seen that the fitting of bolt stays very materially reduces the circumferential stresses in the two cylindrical plates, but it must not be overlooked that the pull of these stays sets up the same class of bending stresses as in flat plates. Thus, in the case of the outer shell, we have $\frac{10}{16}$in. plates and 14 × 14·1in. pitches, for which the permissible pressure would be 61lbs. per square inch if dealt with as being a flat plate. But the partial pressure p_4 is 71·4lbs., which creates a bending stress in the outer shell, which is 17 per cent. higher than that due to the permissible pressure of 61lbs. As the circumferential stress S_2 intensifies the maximum bending stress near the stay holes by about 2 tons per square inch, a rather high total stress is the result, and for a working pressure of 200lbs. the resulting stress might be deemed excessive. The permissible pressure on flat plates, stayed like the inner shell, is, as previously stated, 85lbs. per square inch, whereas the partial pressure p_3, which produces bending stresses in this shell, works out at 107·1lbs. per square inch, or 26 per cent. higher than permitted by rules. In this case only $\frac{1}{3}$ ton has to be added for the circumferential stress, but the total stress is certainly higher than intended.

The severe tension stresses in the bolt stays and the severe bending stresses in both shells are due to the comparatively high partial pressures p_3 and p_4. Modifications of the boiler scantlings and dimensions will alter these stresses. Thus, if the thicknesses t_1 and t_2 were to be increased by 10 per cent., p_3 and p_4 would be reduced by 3·4 per cent. The stresses in the stay bolts would be reduced by the same amount, and the bending stresses in the plates by 20·2 per cent. If the diameter of the stay bolt were to be increased 10 per cent., resulting in an increase of 21 per cent. in its sectional area, a, then p_3 and p_4, as well as the bending stresses produced by them in the plates, would be increased 5·77 per cent., and the stress in the stay bolt would be reduced 12·6 per cent. These deductions and a few others are summarised in the following table. They refer, of course, only to this particular superheater, having shells of 108in. and 72in. diam.

When large departures from any previous design are to be made, the changes in the partial pressures and in the stresses can be roughly estimated by a similar process to the above, and subsequently more exact values can be obtained by using the formulæ, which, unfortunately, are rather too complicated for the direct fixing of the scantlings and stayed boilers. For instance, in the above example the customary bending stresses in plates and tension stresses in stays will not be exceeded, while the circumferential compression stress will be reduced to nothing if the cylindrical plates are made $\frac{7}{8}$in. thick, and the stays $\frac{7}{8}$in. diam. With this thickness of plates, but with the stays removed, the permissible working pressure of the internal cylinder would be 68lbs. It cannot, therefore, be said that stays are worse than useless; in any case, they may be of service as safeguards against collapsing of overheated plates, and they may help to keep distorted furnaces in shape. Generally, however, it will be found that the fitting of stays to weak furnaces of donkey boilers intensifies rather than diminishes the stresses to which they are subjected. Estimates of the stresses in existing stayed donkey boilers should prove of interest, for in most cases they would reveal that the stays are subjected to higher stresses than 10,000lbs. per square inch without failing, that the partial pressure p_3 on the inner cylinder is sometimes higher than the actual pressure p_1, resulting in circumferential tension stresses, and that both p_3 and p_4 are something much higher than would be allowed on stayed flat plates. Nevertheless, as there are only three records amongst the Board of Trade reports of the explosions of boilers stayed in this manner, of which two were due to unknown over-pressures, it would not be advisable to condemn it merely because the stresses in these stays and plates are higher than those sanctioned in other parts of boilers.

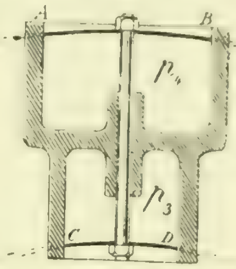


FIG. 2.

Stresses in Stayed Cylindrical Shells. Changes of Partial Pressures and Stresses due to Small Changes of Dimensions.

Dimension Changes.	Resulting Partial Pressure Changes.				Resulting Stress Changes.				
					Stays.	Inner Shell.		Outer Shell.	
	p_3	p_4	p_2	p_1	Tension.	Bending.	C'pression.	Bending.	Tension.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
+ 10 per cent. plate thickness	− 3·4	− 3·4	+ 28·3	+ 5·0	− 3·4	− 20·2	+ 16·6	20·2	1·5
+ 10 per cent. stay diameter	+ 5·8	+ 5·8	− 47·9	− 8·5	− 12·6	+ 5·8	− 47·9	+ 5·8	− 8·5
+ 10 per cent. outer radius, r_2	+ 1·3	− 7·9	− 11·2	+ 22·6	− 7·9	+ 1·3	− 11·2	− 7·9	+ 1·3
+ 10 per cent. circumferential and + 10 per cent. vertical pitches	+ 15·2	+ 15·2	126·3	− 22·3	+ 39·4	+ 39·4	126·3	+ 39·4	− 22·3

SOME POINTS IN SWITCHGEAR DESIGN.

IN a paper recently read before the Arc Works Engineering Society Mr. A. G. Collis pointed out some misconceptions of terms in switchgear work and their results. The first instance of a misconception was, he remarked, involved in the term "Reverse-current device for alternating-current circuits." For alternating-current work the title was quite wrong. A current which at every instant flowed in the opposite direction to the generated electromotive force was reversed or 180° out of phase. If the current lagged or led by 90°, then during half its cycle it was flowing in the direction of the electromotive force and in the other half opposing the electromotive force. This then would be a reverse current, but would not be so designated if the conception of "reversal of energy" was applied. It was doubtful if reverse alternating-current relays were satisfactory. Manufacturers ran a risk of heavy penalties in the event of the apparatus failing, unless well-defined terms were used in the contract. The author gave the following as an example: A 1,500 kw. set was being paralleled with a 5,000 kw. set on a load of 7,000 kw. Owing to a slight reverse current, the 5,000 kw. set dropped off the bars, and

the other set was burnt out. Owing to the indiscriminate use of terms in the contract, the suppliers suffered a loss of £4,000. In one large power station the reverse relays were found to be affected by wattless currents flowing between the machines, and they were now disused. The choker synchronising gear adopted some years ago by Crompton & Co. was very good, and it was difficult to understand the reasons for its discontinuance.

"Gas-tight Switches" was another case of the misuse of a term, as most switches so described were not really gas tight, and in mining work were often dangerous. Explosion-proof switches, fitted with wide flanges were also dangerous. As the force of the explosion of fire-damp was about 200lbs. per square inch, the casing of the switch must be strong. For real safety the arc must open under oil. Switches constructed on the Davy lamp principle were, in his opinion, not satisfactory unless the dust which accumulated on the gauze was periodically removed. Some of the material which goes down into pits, especially that of foreign origin, was worthy of the rubbish heap only.

Perhaps the specific rating of switches was one of the most absurd things in the electrical industry. Generally a specification included a condition that a switch must be capable of breaking a given kilowatt capacity without any allusion to the condition of service. This statement by itself was of no use, and did not protect the buyer. The question of power factor was of great importance. A switch that would break 10,000 kw. at unity power factor would not rupture half this if the power factor was only 0·7, because when the current was zero there was an electromotive force tending to restore the circuit. There was also the question of internal and external reactances. In order to limit the flow of energy into a short-circuit, reactances were introduced into either the generator or transmission circuits. Internal reactance decreased the strain on the end turns of generators and external reactance introduced additional strains in the end-turn windings. Their use, in the author's opinion, was not advisable, as the safeguards might themselves introduce greater evils than those they were intended to eliminate. The conditions were less severe if a switch opened on the downward portion of a wave, instead of on a rising wave. A switch should also be quick acting, so as to open a circuit during one to three current waves, instead of seven to nine or more waves. Resonance effects were not frequent, but must be guarded against, and discrimination must be shown in earthing the neutral points of a system by means of a choking coil or resistance.

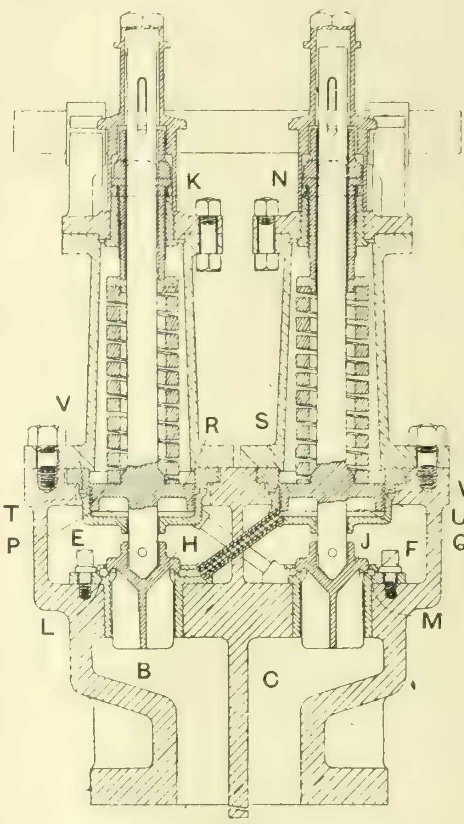
COCKBURN'S DUPLEX SPRING SAFETY VALVE.

THE accompanying sectional view shows a design of spring safety valve of the duplex type, the invention of Mr. D. Cockburn and Mr. D. MacNicoll, of Cockburns, Ltd., Cardonald, near Glasgow. In this arrangement, one valve is loaded to a lesser extent than the other, and annular spaces are formed around both valve seats, passages being provided which establish constant communication between these spaces and chambers fitted with pistons operatively connected to the valves proper, the arrangement being such that under normal conditions the lighter loaded valve is first raised, on the pressure reaching a predetermined amount, so as to permit pressure to act on the piston of the heavier loaded valve and lift this valve to any desired extent; while in the event of the lighter loaded valve not being lifted first, by reason of friction or other causes, the heavier loaded valve will be lifted and permit pressure to pass to the piston of the lighter loaded valve and thus lift the last mentioned valve to any desired extent.

Referring to the illustration, the safety valve comprises a casing having inlet spaces B and C divided by a rib and outlet spaces E and F divided by a rib and leading to a chamber in communication with the atmosphere. The valves H and J proper normally rest on seats, these seats being provided with annular spaces L and M. The valve spindles project upwardly through the ends of cylindrical chambers P and Q, and have attached thereto pistons R and S. The walls of the chambers P and Q are formed with annular spaces T and U associated with one or more perforations V and W which communicate, respectively, with the annular space L and chamber Q, and with the annular space M and chamber P, each of these passages being afforded by means of a pipe within which is fitted a screw-threaded spindle for the purpose of retarding or baffling the flow of fluid pressure through the passages.

Springs rest on the pistons R and S, at the sides remote from the valves H and J, these springs being arranged within casings provided at their upper ends with covers fitted with bushes which are screw-threaded internally to receive compression screws K and N, these screws being adapted to press on washers resting on the springs, so as to vary the load on the valves H and J. The valve spindles are extended through the compression screws K and N and at the top are provided with slots through which are passed cotters fitted to caps, whereby the valve spindles, and thereby the valves H and J, may be raised on actuation of manually controlled arms.

The action of the valve is as follows: Assuming the valve H to be the lighter loaded valve, when a predetermined pres-



COCKBURN'S DUPLEX SPRING SAFETY VALVE.

sure is reached on the inlet side B, the valve H is raised off its seat and admits fluid pressure to the annular space L. The fluid pressure then flows through the passage E to the chamber Q and acts on the underside of the piston S, thereby raising the valve J off its seat and permitting free egress of fluid pressure from the inlet C to the outlet F. Just as the valve J is being raised, and before it has permitted communication between the inlet C and the outlet F, there is a momentary tendency of the fluid pressure to pass to the chamber P and thus cause the valve H to be raised off its seat, but this is prevented by means of the aforesaid retarding or baffling device. Any fluid pressure passing the piston R or piston S flows into the annular space T or U and thence through the perforation or perforations V or W into the outlet space E or F. In the event of the valve H not being raised off its seat, by reason of friction or other causes, then the valve J will be acted upon first and the valve H then raised in a manner similarly to the valve J, as above described.

West of Scotland Iron and Steel Institute.—The sixth meeting of the session of the West of Scotland Iron and Steel Institute was held on the 14th inst. at Glasgow, Mr. Walter Dixon, president, in the chair. A paper by Prof. A. Campion, F.I.C., and Prof. J. G. Longbottom, A.R.C.S., M.I.Mech.E., on "The Relative Properties of Acid and Basic Open-hearth Steel" was read. Following this, Mr. E. de Bruyn gave a lecture on "Recording Instruments and their Application to Modern Works Control."

SOME EFFECTS OF SUPERHEATING AND FEED-WATER HEATING ON LOCOMOTIVE WORKING.*

BY F. H. TREVITHICK AND P. J. COWAN.

THE tendency in recent years to increase train loads and average speeds has, in the main, resulted in larger locomotives. By putting proportionately more weight into the boiler, the evaporative capacity has been increased, and, since boiler capacity limits the tractive effort at anything above low speeds, this has been quite a logical development. The same provision, at equal loads, results in increased economy, since the rate of firing is brought down to a point where the boiler efficiency is greater. This will be evident on reference to Fig. 1, reproduced from Mr. Lawford H. Fry's paper on "Combustion and Heat Balances in Locomotives."† This represents the series 200 of the St. Louis tests on the Pennsylvania Railroad Testing Plant,‡ and has been selected as illustrating the performance of a brick arch boiler, with coal approximating to some English qualities, though reported to be somewhat friable, and as covering a wide range of working. The proportion of the total heat utilised in steam production will be seen to fall as the rate of firing increases; the losses increase rapidly. Clearly, improvement will be effected if capacity sufficient for the production of equal or equivalent output at reduced rates of firing can be arranged for. Fig. 1

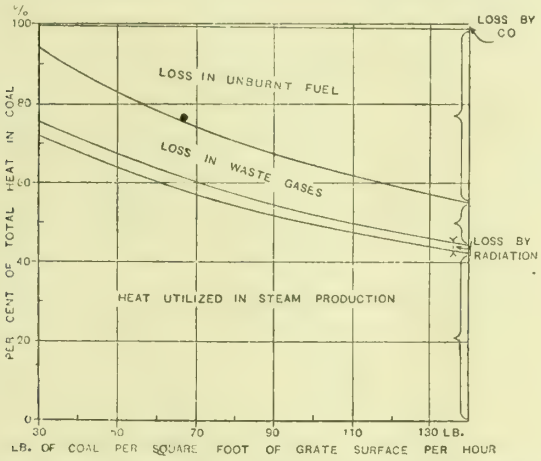


FIG. 1.—RELATIVE AMOUNT OF HEAT UTILISED AND LOST AT DIFFERENT RATES OF FIRING; ST. LOUIS TESTS (Series 200). From Proc., Mar., 1908, p. 275.

shows the nature of the losses. That by radiation is small. It is practically unavoidable, and, comparatively speaking, little would be gained by its elimination, if such were possible. The loss by CO is also negligible. The remaining losses are important, and consist in heat carried away in the gases of combustion passing out of the chimney, and in heat lost in unburnt or partially-burnt fuel.

Fig. 1 is rearranged in Fig. 2 in the form of a diagram of heat available, taking 14,500 B.Th.U. as a typical calorific value for the coal. The line *a* represents the total heat available in the fuel at any rate of firing per square foot of grate area per hour. This diagram is merely typical. A comparison of numerous published results shows that it may fairly be taken to be so. As it is intended to pay attention now only to the larger and more easily preventable losses, the losses by CO and by radiation have been combined in Fig. 2.

In locomotive operation, engine output, steam output, rate of firing, draught, smokebox temperature, and other factors are interdependent. Engine output for a large part of the range of working is limited by boiler output, which is dependent upon the rate of firing. This, in its turn, depends on draught, which, other conditions being unaltered, is a function of the steam exhausted. Fig. 3 (considered in conjunction with Fig. 2) shows the relation of draught to the phenomena accompanying increased output. The upper and lower lines show, respectively, the vacuum recorded in the smokebox at the back of the diaphragm, and the effective draught—that is, the difference between this and the vacuum measured in the firebox. The vacuum in front of the diaphragm in American engines is often twice as intense as that behind it.

* Paper read before the Institution of Mechanical Engineers, March 14th, 1913.
† Proceedings, I.Mech.E., 1908, Part 2, page 275.
‡ "Locomotive Tests and Exhibits," published 1905 by the Pennsylvania Railroad Company.

The net loss of heat in the waste gases is dependent upon their quantity and specific heat and the smokebox temperature. In quantity the waste gases increase with the rate of firing, though the amount of gas per pound of fuel burned tends to diminish. The manner in which smokebox temperatures increase with the rate of firing is shown in Figs. 4 and 5. Such diagrams are given as straight line curves in the St. Louis report, but this is really incidental to plotting to too small a scale. The St. Louis tests on modern large boilered engines show lower temperatures than the Purdue

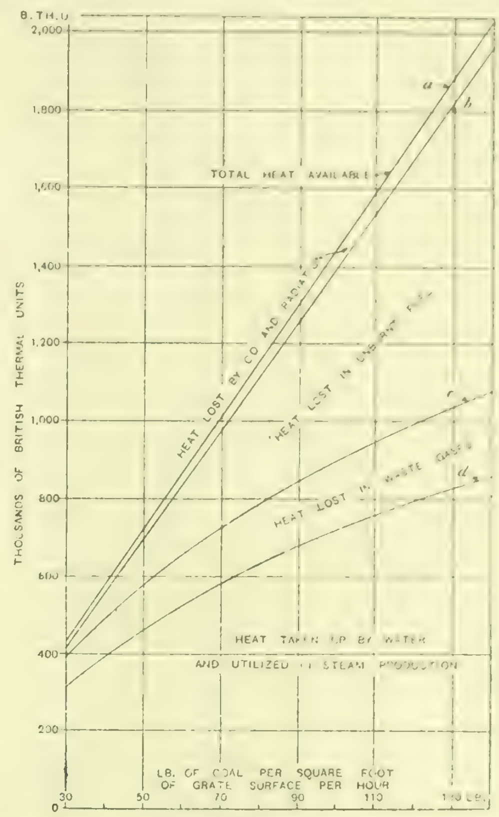


FIG. 2. HEAT UTILISED AND LOST AT DIFFERENT RATES OF FIRING; BASED ON ST. LOUIS TESTS (Series 200).

tests represented in Figs. 4 and 5. The specific heat of the waste gases increases with smokebox temperatures.* As a net result of the combination of these three factors, the proportion of the loss in the waste gases to the heat available in the coal gradually falls, but in amount increases with the rate of firing.

Of the loss by unburnt fuel, part, occurring at the grate, is not usually preventable, except such as arises from inexpert firing. The larger portion of this loss is involved with engine output and draught. The greatest loss is traceable to the quality and quantity of the smokebox cinders, and of those

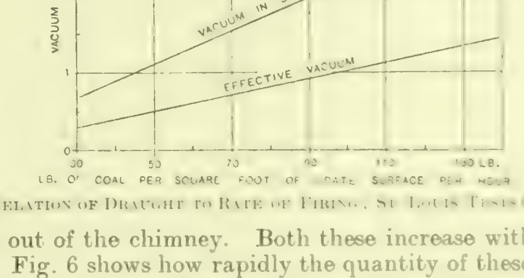


FIG. 3 RELATION OF DRAUGHT TO RATE OF FIRING, ST. LOUIS TESTS (SERIES 200).

passing out of the chimney. Both these increase with rate of firing. Fig. 6 shows how rapidly the quantity of these cinders increases at the higher rates of firing. Other classes of coal may show losses on an even heavier scale. The smokebox cinders, and those passing out of the stack, have been combined in Fig. 6. It is not possible to state definitely what effect the rate of firing has on the relative amounts of these two cinders losses, but it appears probable that so long as the smokebox capacity is not taxed, the smokebox cinders are greater in amount than those passing out of the chimney when

* Proceedings, I.Mech.E., 1908, Part 2, page 281.

work is light, and that when the engine is forced, those emitted from the chimney exceed those retained in the smokebox. This opinion is supported by Dr. Goss, and by figures given in a paper read before the Western Railway Club in 1898 by Mr. W. Garstang. In general, it may be taken that, at fair engine rating, the loss by cinders ejected is large, and on ordinary runs exceeds the amount which accumulates in the smokebox, the proportion of cinders ejected to cinders in the smokebox being often two or more to one, in smokeboxes

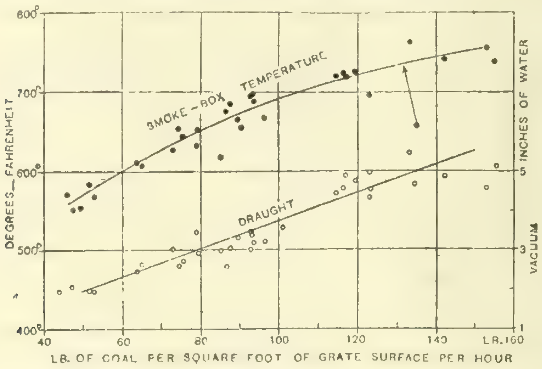


FIG. 1.—RELATION OF SMOKEBOX TEMPERATURE AND DRAUGHT TO RATE OF FIRING; VALUES FROM GOSS'S "LOCOMOTIVE PERFORMANCE" ("Brazil block" coal).

fitted with netting. This factor is, however, largely dependent upon the quality of the coal, as is also the quality of the cinders.

Fig. 7 gives an idea of the way in which the calorific value of these cinders increases with rate of firing. The curves are for three different kinds of coal. Their value is thus high, being shown to be about 90 per cent. of the original value of the coal at the highest rates of working. In the St. Louis tests the highest calorific value found for smokebox cinders was 95 per cent. of the value of the original coal, and for the cinders ejected 87·6 per cent. of the coal value. The average for all tests was for smokebox cinders 80·7 per cent., and for cinders ejected through the chimney 72·5 per cent. of the original value of the coal. Determinations, made in connection with Egyptian State Railways passenger engines using Welsh coal, have shown a calorific value, for smokebox cinders, equal to 86 per cent. of the original coal value. Usually the cinders ejected have a rather lower value than those retained

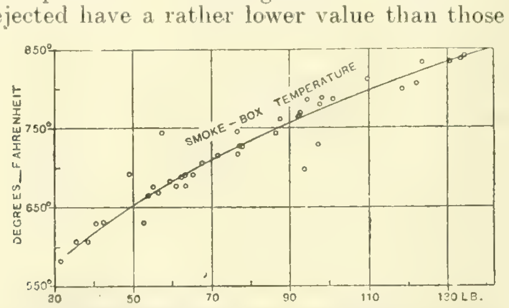


FIG. 5. RELATION OF SMOKEBOX TEMPERATURE TO RATE OF FIRING; VALUES FROM GOSS'S "HIGH STEAM PRESSURES IN LOCOMOTIVE SERVICE" (Youghiogheny coal).

in the smokebox, though circumstances may arise where the reverse is found to be the case.*

Reduction of Boiler Losses.—The facts exhibited in Figs. 1 to 7, which show so rapid an increase in the boiler losses at the higher rates of firing, emphasize the statement already made that improvement will be realised if the necessary output can by some means be secured at a reduced rate of firing. Within limits, increase in boiler capacity is thus as logical from this point of view as it is when made in order to meet demands for more power. This solution, however, has certain drawbacks. With the enlargement, radiation and grate losses increase, the latter becoming important in intermittent work. An increase in total engine weight is also involved, and, as permanent way considerations limit this, the time will come, and has now been reached in cases, when improvements must be sought, involving an increase of weight on a reduced scale. The logical alternative to the increase of boiler capacity is to relieve the boiler of part of its work, by the adoption of some supplementary process, which; however, to be successful, must necessitate a comparatively small increase in weight. Two processes which meet this requirement are feed-water heating and steam superheating.

Feed-water Heating.—In feed-water heating part of the boiler work is accomplished before the water passes the clack. For feed-heating agents, providing a direct saving of otherwise waste heat, there are available the exhaust steam discharged from the cylinders, and the waste gases passing out of the chimney. Feed-heating can be accomplished by either of these, alone or together in series. If used in series, heating by the waste gases must be accomplished last. As the process may be arranged to result in temperatures being reached at which even the so-called hot-water injectors will not work, its successful adoption involves a reconsideration of the feeding system generally.

The ordinary injector will not pick up water above about 120° to 125° Fah., and the feed cannot, therefore, be effectively heated before it reaches the injector, while the admixture in that apparatus of live steam with the feed so raises the temperature of the latter that full advantage cannot be taken of subsequent heating by either of the agents available. An injector may feed into a boiler at 180lbs. per square inch pressure, about 11·2lbs. of water for every 1lb. of steam used. If the supply be at 65° Fah. the delivery will be about 160·5° Fah. This increase is not an economic gain. Delivery falls off as the boiler pressure rises, and the temperature of delivery is higher at the higher pressures. Subsequent feed-heating is of less advantage now than it would have been when pressures were lower.

For each 1lb. of steam used in the cylinders (1 + a fraction) must be produced in the boiler, from the temperature of the injector discharge, in order to supply both the engine and injector. The B.Th.U. thus to be produced are given for various pressures in Fig. 8, by Curve No. 1, which is based

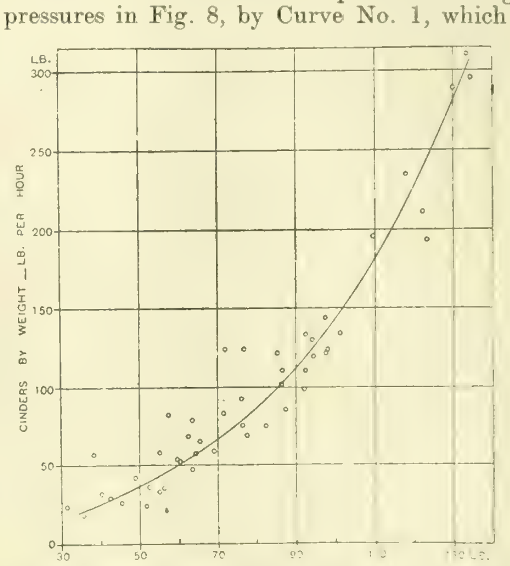


FIG. 6. RELATION OF WEIGHT OF CINDERS PASSING THROUGH THE BOILER TUBES TO RATE OF FIRING; VALUES FROM GOSS'S "HIGH STEAM PRESSURES IN LOCOMOTIVE SERVICE" (Youghiogheny coal)

on data published by Mr. S. L. Kneass.† If, subsequent to delivery from the injector, the feed be heated by the cylinder exhaust to 210° Fah., the boiler work is reduced, as denoted by Curve No. 2. The work needed increases with the boiler pressure. Heat can further be transmitted from the waste gases, and an average feed temperature of 280° Fah. to 290° Fah. obtained, but compensation can in no way be secured for heating during part of the process with live steam.

At modern pressures the ordinary exhaust injector shows a thermal saving over the live-steam injector of some 9 per cent. The supplementary portion of the exhaust injector is handicapped by the water fed to it being already at a high temperature (about 180° Fah.). Its steam consumption is thus high, and the final temperature of discharge is about 280° Fah. Additional feed heating is thus impracticable, even by the waste gases. The only gain procurable with this injector is that due to the use of part of the exhaust steam. This, however, may exceed the thermal gain of 9 per cent. or so. In a more recent form of exhaust-steam injector the efficiency of the exhaust steam jet has been improved, and much less supplementary live steam is needed. Though the thermal position

* Dr. Goss's report on "Superheated Steam in Locomotive Service."

† "Practice and Theory of the Injector." Wiley.

is the same with both types, the discharge temperature is thus lower with the later pattern. The final temperature with the later type is 195° Fah. compared with 280° Fah. with the earlier, and further feed-heating is practicable.

The pump offers advantages over the injector in connection with feed-heating, since, with it, the feed temperature is not increased in the process of raising the pressure, and the temperature head is sufficient for the effective transfer of heat to the pump delivery, successively from the exhaust steam and the waste gases. On account of the sudden demands which a locomotive feed pump is called upon to meet, such an appliance should be arranged to work with water at moderately low temperatures, and the greater part of the feed-heating process should be carried out between the pump and the boiler clack.

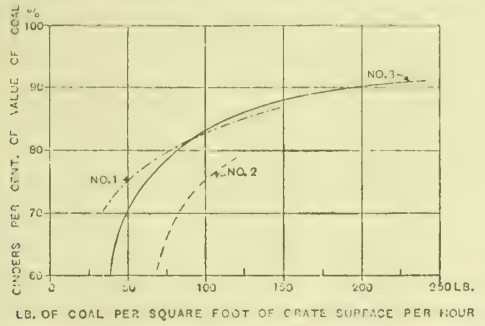


FIG. 7.—RELATION OF CALORIFIC VALUE OF CINDERS PASSING THROUGH THE BOILER TUBES TO RATE OF FIRING; VALUES FROM GOSS'S: No. 1, "SUPERHEATED STEAM IN LOCOMOTIVE SERVICE" (Pocahontas coal); No. 2, ditto (Youghiogheny coal); No. 3, "LOCOMOTIVE SPARKS" ("Brazil block" coal).

Independent steam pumps suitable for locomotive work will deliver 100lbs. of water for about 1·5lbs. of steam, working at and against 180lbs. pressure. Curve No. 3, Fig. 8, shows the B.Th.U. to be provided by the boiler for each 1lb. of steam delivered to the cylinders, using pump supply and feed at 65° Fah. Curve No. 4 shows the work required if the pump exhaust be utilised for feed heating, about the same amount being required at all pressures. The pump and injector are then on an equal footing at moderate pressures. Heating, further, by the main cylinder exhaust at 210° Fah. reduces the boiler work to the amounts shown by Curve No. 5. This system has a considerable advantage over the injector feed combined with heating to 210° Fah. (see Curve No. 2), and this is maintained if the feed-heating be carried still further.

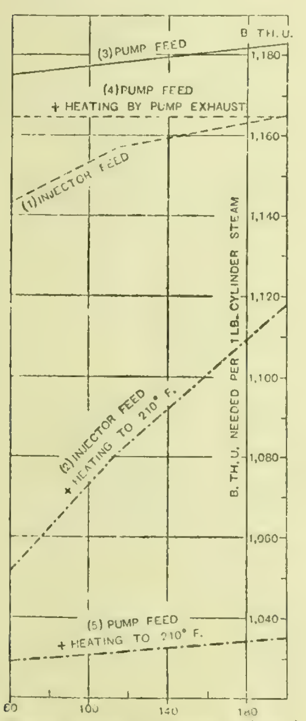


FIG. 8.
SATURATED STEAM BOILER OUTPUT IN B.TH.U. NECESSARY WITH VARIOUS CONDITIONS OF FEED, FOR EACH LB. OF STEAM USED IN THE CYLINDERS.

Superheating.—In superheating, a final benefit may be due to different causes according to the system. In one system the heat in the waste gases discharged from the boiler is utilised to raise the temperature of the steam. In another a directly-fired superheater is employed, commonly incorporated for convenience in the boiler, in order that one grate may serve both. Hybrid systems have also been tried, in which either the ordinary boiler tube length has been curtailed and a superheater added in the space thus provided, or a large supply of "live" gas has been conducted to a smokebox heater through a special flue. Most of these latter systems have been abandoned. They lower the efficiency of steam generation, and this is not sufficiently recouped in the engine for these arrangements to compare favourably with others.

Contrary to general experience in other branches of steam engineering, and also in conflict with testimony from many railways, it has been maintained that waste-gas superheating effects little or no benefit in locomotive work. This system combines improvements in two directions, namely, in the efficiency of steam generation and in the engine's consumption. The gain in generation has been commonly ignored or actually denied so far as locomotive work is concerned, while the engine gain has been fairly generally admitted. A true waste-gas superheater forms an adjunct to the ordinary boiler. Its installation should not disturb the heating capacity of the boiler, nor alter its efficiency. About the same proportion of the heat of combustion is taken up by the water-heating surface as where no superheater is fitted, and to the steam thus produced is added further heat abstracted from the waste gases. The overall efficiency of the generator is improved, the proportion of heat available in the coal, put to use, being increased. Directly-fired superheater locomotives, using superheat from 100° Fah. upwards, which can lay claim to no improvement in the efficiency of steam generation, but rather suffer in an adverse sense, admittedly prove satisfactory in service. There appears, therefore, to be no valid reason why the waste-gas heating system, with which superheat of about 90° Fah. can be obtained, should not likewise give good results. The difference between the temperatures just cited is more than made up by the higher overall efficiency of the combined waste-gas heater and boiler. The temperatures claimed for waste-gas superheaters are sometimes too high. Something over the figure just quoted is, however, perfectly practicable.

It is difficult to determine the economical position of directly-fired superheater installations of the moderate degree or high degree types, as applied in locomotive service. For the generator efficiency to be undiminished, no more heat must be lost from a superheater boiler than in the ordinary boiler. In some installations the average amount of heat absorbed through the smoke-tube superheater surface may about equal,

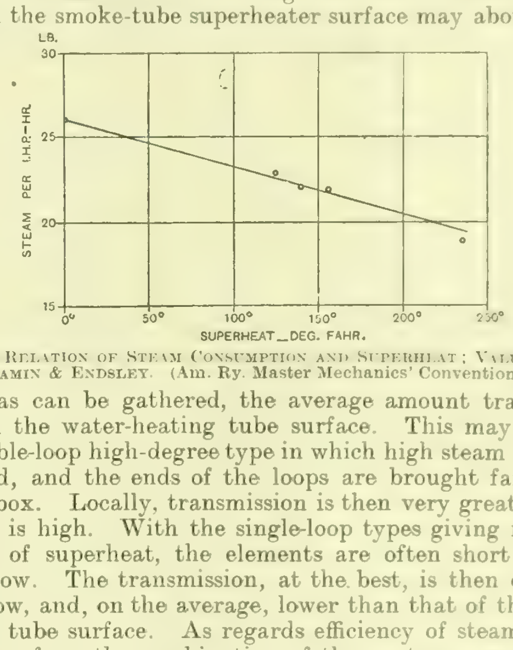


FIG. 9. RELATION OF STEAM CONSUMPTION AND SUPERHEAT; VALUES FROM BENJAMIN & ENDSLEY. (Am. Ry. Master Mechanics' Convention, 1911).

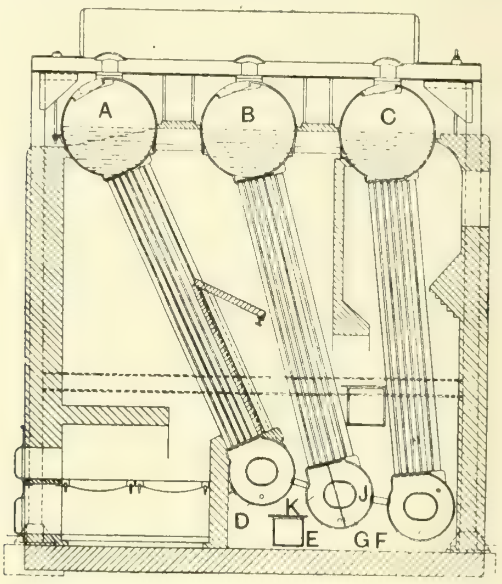
as far as can be gathered, the average amount transmitted through the water-heating tube surface. This may be so in the double-loop high-degree type in which high steam velocities are used, and the ends of the loops are brought fairly near the firebox. Locally, transmission is then very great and the average is high. With the single-loop types giving moderate degrees of superheat, the elements are often short and the speeds low. The transmission, at the best, is then comparatively low, and, on the average, lower than that of the water-heating tube surface. As regards efficiency of steam generation, therefore, the combination of the waste-gas superheater and boiler ranks first. Probably the ordinary boiler ranks second and the high-degree smoke-tube superheater boiler third, but this does not appear yet to have been definitely determined; it is possible their relative positions are not the same at all powers. Last of all stands the moderate degree smoke-tube superheater boiler.

Though the above aspect of superheating is often treated with indifference, it is generally conceded that there is more or less saving in steam at all degrees of superheat. Even with no superheat the use of a heater may reduce the feed necessary, if the steam normally sent over is wet. Part of the economy shown on road tests undoubtedly arises from this. With any temperature above that corresponding to dry steam, there is an improvement in the engine. In stationary work this is not disputed, and the result is similar in locomotive working. This has been determined in road tests, and also on testing plants. Dr. Goss and others responsible for the work at Purdue have concluded that steam consumption falls with increasing superheat, as shown in Fig. 9. This determination is naturally only approximate. The data issued from Purdue constitute the only records yet published, showing the effect of progressive superheat on steam consumption in locomotive service. As regards coal consumption, however, they do not fairly indicate the possibilities of moderate superheating (though it is sometimes held they do), since they do not embrace investigations with the more efficient installations of that class.

(To be continued.)

IMPROVEMENTS IN WATER-TUBE BOILERS.

We illustrate herewith a design of water-tube boiler of the type comprising a plurality of upper steam and water drums and lower water drums connected together by approximately vertical tubes, one of the lower drums being separated into compartments by an imperforate partition arranged longitudinally thereof, which has recently been patented by the Stirling Boiler Company, Ltd., 58, Victoria Street, Westminster, in conjunction with Mr. E. G. Constantine. The imperforate longitudinal diaphragm or partition is fitted in the lower water drum adjacent to that nearest to the furnace grate, and is so arranged that the water is constrained to flow upwards in the rear tubes of the bank and down the front tubes, thus lengthening the path of travel of the water before it is carried to that portion of the boiler immediately over the



Improvements in Water-tube Boilers.

furnace grate. Referring to the illustration, A, B, and C denote the upper steam and water drums, and D, E, and F denote the lower water drums. In the drum E is fitted the imperforate partition or diaphragm G which is so arranged as to cause the water flowing from the drum F to travel upwards through the tubes connecting the rear water space J in the drum E with the drum B, and downwards through the tubes connecting drum B with the front water space K in the drum E, thence into the drum D, instead of flowing in known manner direct from the drum F to the drum D. This diaphragm G, in lieu of being made flat, may be made curved and may be hinged so as to hang clear of the manhole and permit the drum to be inspected on both sides. A baffle (not shown) may be arranged in the central bank of tubes to form an extended path for the hot gases.

THE TESTING LABORATORY AND THE CONSTRUCTING ENGINEER.

In the course of a paper on this subject, read before the American Society of Mechanical Engineers, Mr. H. W. Hayward said that the many grades of materials now obtainable made it necessary to have definite specifications for everything. These specifications must be fair to both dealer and purchaser, and no more rigid than was necessary to obtain the quality of material required. Unnecessarily rigid specifications were apt to cause friction and usually boost the price excessively; and often they were not lived up to. A set of specifications should be so drawn as to ensure the delivery of the exact quality of material desired and leave the manufacturer as much leeway as possible. The engineer should be familiar with the processes of manufacture in order to select the tests that were made with the special object of determining the care used in their manufacture, and the manufacturer should be familiar with the uses to which the materials were to be put. The two could be brought together by common interest in a testing laboratory where the qualities of the materials could be determined, and tests made upon full-sized specimens.

There were several kinds of laboratories for physical tests of structural materials—single testing machines in works; works laboratory, special and complete; testing company's laboratory; government; and technical schools. A single testing machine in a manufacturing plant was usually operated by an unskilled man, and showed as a rule only one quality of the material tested. Works laboratories varied considerably in scope and capacity, some of them being very complete as regards the special requirements of their respective works. While being of great assistance in controlling the processes and quality of the materials produced, they did little work in any other direction. The men operating them were usually not of a high order of intelligence, and even the men in charge were sometimes rather narrow in their views and considered the makers' standpoint only. A few large companies maintained laboratories conducted by most skilful and capable men who carried on work along all lines connected with the industry, and obtained valuable data, many of which were published for general information. Private testing companies did splendid work for their clients. The U.S. Government had extensive testing laboratories equipped with all necessary apparatus, and was doing very elaborate research and service work. The work was carried on, however, very slowly, and no results were published until the investigation was complete in every detail. The work was done primarily for the Government, and private individuals must untangle a great deal of red tape before anything could be done for them. The Bureau of Standards should furnish the profession with a standard method for testing the accuracy of testing machines.

The laboratories of technical schools filled in a wide gap. In them an equipment of great variety was usually provided to satisfy the requirements of tuition, thesis work, and research. In addition, technical school laboratories must be prepared to carry on commercial tests at all times, and much could be done in this connection if engineers could be persuaded to put more of their questions up to technical school laboratories at the proper time for thesis work.

The specimens for the tests to determine if a material passed specification must be properly selected, must be of the required size and shape, and taken from the proper place. As a matter of fact, specimens were often submitted in an entirely unsatisfactory manner, *e.g.*, just 8in. long when it was required to determine the elongation in 8in., no extra length being left for the grips of the testing machine. For testing properly the ratio of diameter to length, sufficient metal for unrestricted flow should be maintained, if elongation tests were to be considered and correct values obtained.

The condition of testing machines must be thoroughly watched. The weighing system was often out of order and the heads might be out of line; the latter had a great effect on short, brittle specimens, such as cast iron, where the eccentric load caused a much lower strength to be recorded than was the actual case. The screws for the buffers should also be watched.

On the whole, specimens should be tested in a manner to bring out the care in the manufacture of the material, and to show any inferior quality from any source. No unnecessary tests should be specified. Some tests usually left out of specifications were, in the opinion of many engineers and manufacturers, more valuable than many of those that were included, *e.g.*, reduction of area in ductile materials, especially for high grade steel or wrought iron, instead of elongation only. Twist tests for copper wire belonged to the same class. The tests specified must be as simple as possible, so that they might be carried out in any fairly equipped laboratory at a minimum expense. Quantitative tests for the specifications of manufactured parts, columns, girders, slabs, pieces of machines, &c., were a much more difficult problem than the qualitative tests of materials from which they were fabricated, and could be made only by laboratories well equipped with apparatus and force. These tests must approximate working conditions as nearly as possible, and must furnish data for the design of the parts.

It was encouraging to note that many engineers and

manufacturers were taking up with great enthusiasm the question of testing parts of machines and structures or even complete machines, and were successfully standardising their products. Many engineering firms, with the help of testing laboratories, were getting up specifications covering the complete line of materials used by them, effecting thereby a great saving in trouble and money. Much, however, remained to be done.

Many terms used in connection with structural materials were in a rather mixed state, such as elastic limit, yield point, strain, &c. Quantities that could not be obtained exactly, *e.g.*, elastic limit or yield point of copper or bronze, should not be specified. New qualities of materials were being continually brought out which required special tests. This was especially true with regard to the compound steels and alloys which were being used for shafts, gears, and other parts of running machinery. To determine their value such metals must be tested for repeated stress and shock resistance. The variation in quality due to treatment in these high-grade steels and in many alloys made chemical tests, though of value in some cases, almost useless in others.

The author gave the following interesting information: Ductile material elongated when twisted; modulus of elasticity of piece of high carbon steel was the same as for soft, within the elastic limit; a crystalline fracture on soft rivet steel could be obtained by gradual tension; steel of great strength might be very ductile; fibre rope could be made to break in the centre if held by eye splices properly made and wet; steel or copper cable could be broken if held in cast sockets; best rivet steel could be nicked and bent without cracking open.

METAL FILAMENT LAMPS.*

BY ALEXANDER SIEMENS.

DR. M. v. PIRANI published in "Helios (No. 46 of 1912) an article on the development of modern glow-lamps, which starts by repeating the fundamental necessity of every technical development being guided by the requirements of the consumer. Foremost among these is economy in the true sense of the word; that is, low first cost combined with low cost of maintenance. In the case of glow-lamps this means low first cost, long life, and a small consumption of current; but, in addition, such a lamp should be adaptable to existing electrical conditions (varying voltages) and to existing local conditions, which determine its shape and size: and, lastly, that it should not be too sensitive to rough treatment.

All these requirements, except one, are fulfilled by the carbon filament lamp; but its high consumption of current (3·5 watts per candle) at one time endangered the superiority of electric illumination over gas lighting, which, stimulated by competition, had become so economic that the extension of electric lighting was visibly checked. Curiously enough, the same man whose invention of the "mantle" converted gas into such a formidable competitor of electricity, was the first to manufacture a glow-lamp with an osmium filament using only half the watts per candle, compared with the carbon filament lamp. Unfortunately, this first metal filament fell short of the carbon filament in other respects: it was exceedingly brittle, it became soft at a comparatively low temperature, so that a lamp with horseshoe filaments could only be used in a vertical position with the filaments hanging downwards, because they could not be stayed in any other position, as they shorten perceptibly when heated. Finally, it could only be manufactured for low voltages.

The further development of the osmium lamp was interrupted by the appearance of the "Nernst" lamp, invented by Prof. Nernst, of Göttingen. By employing a conductor of the second class he succeeded in producing light by means of short, comparatively thick, rods capable of supporting themselves and as economical in current as the osmium lamps, although the loss of heat by conduction is considerable owing to the rods glowing in air. But there are drawbacks, the principal one being that the cold filament does not conduct electricity, so that some special provision has to be made in each lamp to heat up its filament; another drawback is the property of the filament that its resistance rapidly decreases with increase of temperature. On this account it is necessary to insert a resistance in series with each lamp to guard against the effect of variations of voltage.

A decided step forward was the introduction of the tantalum lamp announced by Dr. W. von Bolton and Dr. O. Feuerlein in the "Elektrotechnische Verein" (Berlin), January 17th, 1905—E.T.Z., Heft 4, 1905. They described the research work which had been carried on in the laboratory of the glow-lamp works of Siemens and Halske, in Charlottenburg, to discover methods of producing the rare metals in a commercially possible manner, and then to try one after the other as filaments of glow-lamps. Beginning with vanadium and niobium, Dr. von Bolton found their melting point too low for obtaining results superior to carbon filaments. In these cases he had followed the same method of working that Dr. Auer had adopted for the production of osmium; the metallic oxide had been mixed with a suitable reducing agent, squirted into thread-form, and heated in a high vacuum. Proceeding to experimenting with tantalum in the same

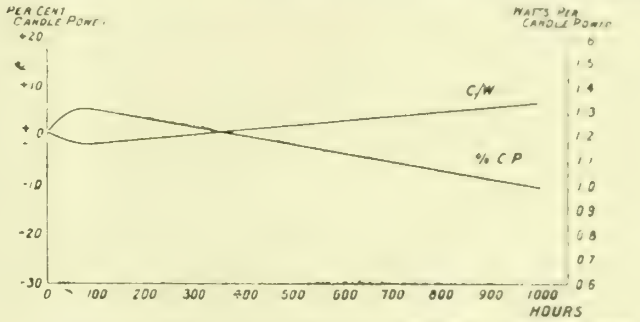


FIG. 1.—ALTERATION OF CANDLE-POWER AND OF WATTS PER CANDLE WITH TIME. WOTAN LAMPS OF 10 CANDLE-POWER, 110 VOLTS.

manner, he obtained a minute globule of metallic tantalum which proved to be tough and malleable. Thereupon he melted metallic tantalum powder, produced by the methods of Berzelius and Rose in vacuo, and obtained pure metallic tantalum which can be hammered and drawn into wire suitable for filaments.

As tantalum has a very much lower specific resistance than carbon, the filaments of tantalum lamps, at equal voltage and equal candle-power, have to be two and a half times the length and one quarter the diameter of equivalent carbon filaments; *e.g.*, at 110 volts and 25 c.p. the length of a tantalum filament is 645 mm. and its diameter 0·047 mm. against a carbon filament 250 mm. long and 0·18 mm. diam. Moreover, the softening of the wire at the working temperature made it impossible to imitate the double or treble loop of a carbon filament. After a good many trials, a satisfactory solution of this problem was found by winding the filament zigzag fashion

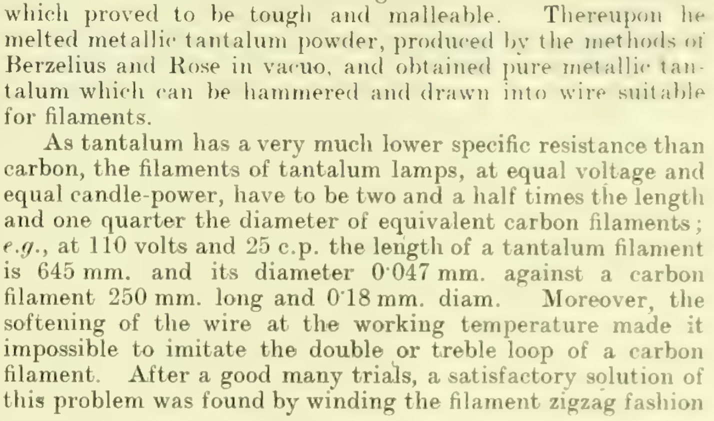


FIG. 2.—ALTERATION OF CANDLE-POWER AND OF WATTS PER CANDLE WITH TIME. WOTAN LAMPS OF 50 CANDLE-POWER, 220 VOLTS.

between two star-shaped supports. In this way detrimental alterations in the position of metallic filaments are successfully prevented. Further data about tantalum will be found in a Friday-evening discourse delivered by the author at the Royal Institution on April 23rd, 1909, and about the history of metal filament lamps in three articles of "The Engineer" in December, 1906.

As the tantalum filament had all the good qualities of the carbon filament, but consumed only about half the current for the production of the same illumination, it found a ready application everywhere, 103 million tantalum lamps being put on the market during the seven years since January, 1905. Even this great success did not stop the endeavours to utilise metals with even higher melting points than tantalum. One of these is tungsten, melting at about 3,000° C., but it was

* Paper read before the Institute of Metals, March 1913.

generally known to be too brittle to be drawn into wire. To overcome this difficulty, Just and Hanaemann heated a carbon filament in an atmosphere of chloride of tungsten whereby it was covered by metallic tungsten. Afterwards the carbon foundation was removed by heating in the presence of hydrogen. Auer produced tungsten filament lamps, calling them osram lamps, by mixing metallic powder with organic materials to a paste which could be squirted into threads, the additions being removed by heating in hydrogen. A third method was proposed by Kuzel, of Baden, near Vienna, who converted metallic tungsten into the colloidal state and then squirted it into threads which were treated as stated above.

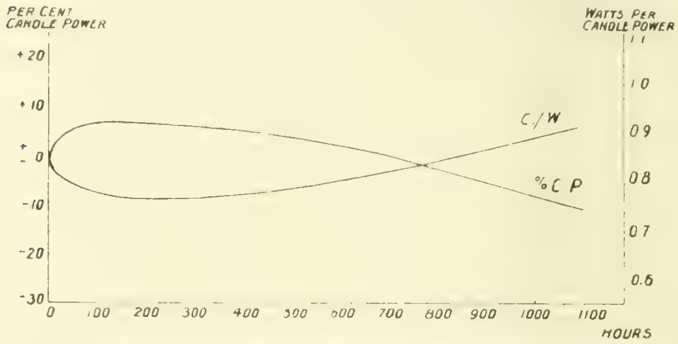


FIG. 3. ALTERATION OF CANDLE-POWER AND OF WATTS PER CANDLE WITH TIME. WOTAN LAMPS OF 1,000 CANDLE-POWER, 110 VOLTS (0·85 W.P./C.).

Differing from these squirting methods was a process employed by Siemens and Halske, who mixed metallic powder of tungsten with at first about 10 per cent. (later on 2-3 per cent.) of nickel, and pressed the mixture into the shape of rods which were heated in an atmosphere of hydrogen up to near the melting point of nickel. These rods were malleable, and could be drawn down to serve as lamp filaments, and their strength exceeded that of the tantalum filament. These filaments when heated expelled the nickel which would have blackened their globes. They had, therefore, to be heated in special containers until they had lost all their nickel before being placed in the usual globes. It was found, however, that their life was quite uncertain.

While the process was being improved, a decisive step forward was introduced by the General Electric Company (U.S.A.), who patented in 1909 a process for making ductile tungsten, which is described in the British patents 23499/09 and 8031/10, and of which the following is the fundamental fact on which the change in the properties of tungsten is based, viz.: that "by repeated mechanical working, the tungsten being heated during the earlier stage of the operations, a condition is reached where the metal acquires such physical or molecular characteristics that further working may, if desired, be continued at room temperatures."

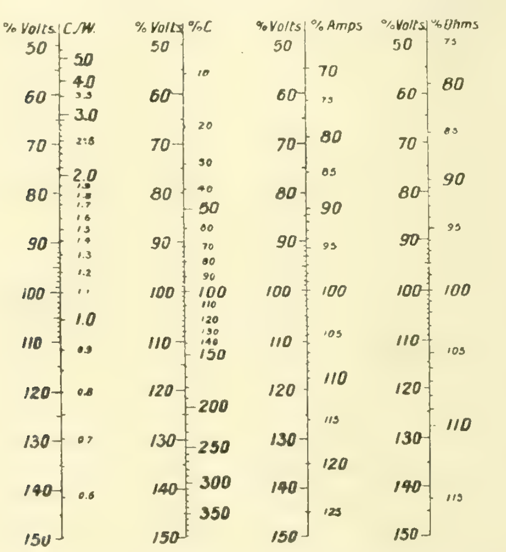


FIG. 4. TABLE SHOWING DEPENDENCE OF C./W. (WATTS PER CANDLE); PER CENT OF CANDLE-POWER, PER CENT. OF RESISTANCE (OHMS) ON THE DIFFERENCE OF POTENTIAL IN PER CENT. IN WOTAN LAMPS (100 PER CENT. = 1·1 WATTS PER CANDLE).

A very full description of the process will be found in the "Zeitschrift für angewandte Chemie," Vol. XXV., Heft 37 (September 13th, 1912), in an article on the production of ductile tungsten by Otto Ruff. He first describes the chemical processes necessary for the production of pure metallic tungsten powder. This is pressed into rods 13 cm. long and 4 sq. mm. in section by a pressure of about 5,000 kg. per square centimetre (equal to about 32 tons per square inch). In order to consolidate these rods, they are at first heated in an atmosphere of hydrogen to about 1,300° C., and afterwards, by passing an electric current through them, to a white heat until the rod is firm enough to be hammered in a swaging machine. The treatment of heating the rod and passing it through a swaging machine is repeated until the dimensions are sufficiently reduced to commence rolling and drawing through diamond dies in the same manner as other metal wires are treated.

Mr. Ruff concludes his article by saying that the finished tungsten wire is silver white and possesses a very high breaking strain, attaining up to 420-460 kg. per square millimetre (266-292 tons per square inch); it is ductile, tough, very elastic, and non-magnetic. In the air, at ordinary temperatures, it does not change, but it oxidises on the surface when heated to redness. Pure hydrochloric acid, nitric acid, or fluoric acid hardly attack it, perhaps on account of the formation of a film of oxide, but it is dissolved slowly by a mixture of hydrochloric and nitric acids, and very quickly by a mixture of strong fluoric acid and nitric acid. Undiluted sulphuric acid attacks it only at high temperatures; for instance, Ruder reports* that at 200° only 1·1 per cent. was dissolved in eight hours. Tungsten wire is not attacked by hydrated alkalis but is oxidised by molten alkalies such as nitrite of potash, or nitrate of potash and chlorate of potash.

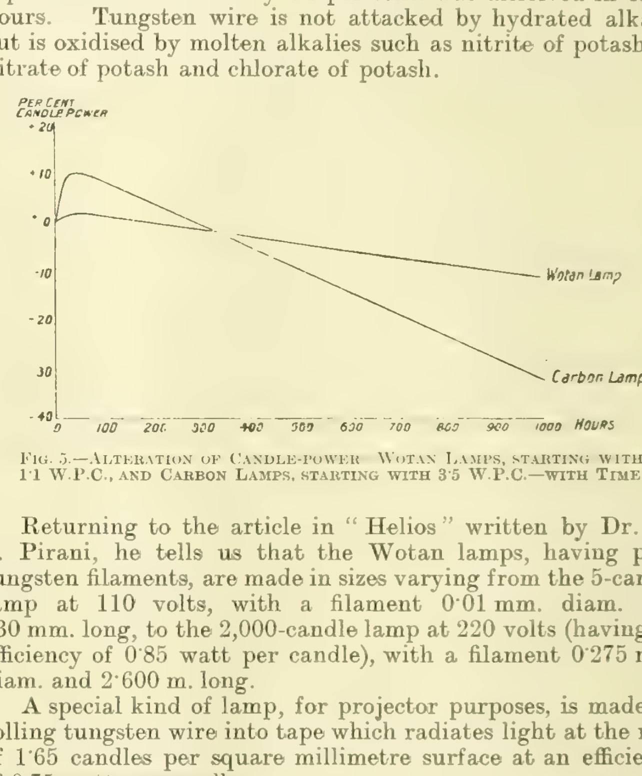


FIG. 5.—ALTERATION OF CANDLE-POWER WOTAN LAMPS, STARTING WITH 1·1 W.P.C., AND CARBON LAMPS, STARTING WITH 3·5 W.P.C.—WITH TIME

Returning to the article in "Helios" written by Dr. M. v. Pirani, he tells us that the Wotan lamps, having pure tungsten filaments, are made in sizes varying from the 5-candle lamp at 110 volts, with a filament 0·01 mm. diam. and 330 mm. long, to the 2,000-candle lamp at 220 volts (having an efficiency of 0·85 watt per candle), with a filament 0·275 mm. diam. and 2·600 m. long.

A special kind of lamp, for projector purposes, is made by rolling tungsten wire into tape which radiates light at the rate of 1·65 candles per square millimetre surface at an efficiency of 0·75 watt per candle.

The alterations in candle-power and watts per candle while the lamps are burning 1,000 hours are shown by the curves, Figs. 1, 2, and 3.

Fig. 1.	10-candle lamp at 110 volts	Starting with
,, 2.	50-candle lamp at 220 ,,	1·1 watt per candle.
,, 3.	1000-candle lamp at 110 ,,	0·85 ,, ,,

A table (Fig. 4) shows the variation of watts per candle amperes and resistance depending on the variation of volts (100—normal). The last curve (Fig. 5) shows the variation of the illuminating power in a Wotan lamp starting with 1·1 watts per candle and in a carbon filament lamp starting with 3·5 watts per candle.

These results, taken together with the high temperature at which the tungsten lamp works, make it very doubtful whether it will be possible to construct a much more economical glow-lamp, so that the consumer will have to look for further economy to the improvement and cheapening of the electric supply.

* Journal of the American Chemical Society, 1912, Vol. XXXIV., p. 387.

COMPRESSED AIR FOR WORKING AUXILIARIES IN SHIPS PROPELLED BY INTERNAL-COMBUSTION ENGINES.*

BY W. REAVELL.

WHEN it is decided to equip a modern steamship with engines of the internal-combustion type, instead of steam engines, for its propulsion, the important problem of how best to deal with the auxiliary machinery demands attention. It is common knowledge that in several cargo boats fitted with this type of engine the maxim of "one experiment at a time" has been wisely remembered, and an auxiliary steam boiler

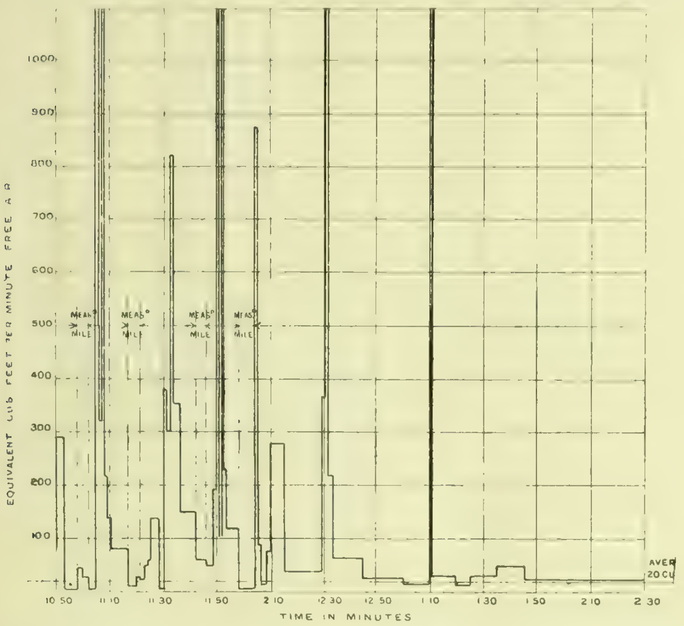


FIG. 1.—DIAGRAM SHOWING VARIATION IN DEMAND FOR STEAM ON THE STEERING ENGINES AT THE TRIAL TRIP OF S.S. "BERWINDVALE."

has been installed for deck winches, steering gear, &c. As confidence in the internal-combustion engine grows, however, a more excellent way will be sought for, and the relatively high fuel oil consumption in the boiler of the auxiliary steam plant which has already been experienced will accelerate that step. The object of this paper is to show the advantages of compressed air for this purpose, and to discuss the conditions under which it can be most efficiently employed. The auxiliaries which, in an ordinary cargo boat, lend themselves at once to separate treatment are the steering engine and the whistle, for even if these are operated by steam in the time-honoured way in a ship with internal-combustion engines, when all the rest of the auxiliaries are worked by steam, it seems unnecessary to maintain steam during the whole of an ocean voyage simply to supply the steering engine or a whistle, and several ships have been, or are being, fitted with

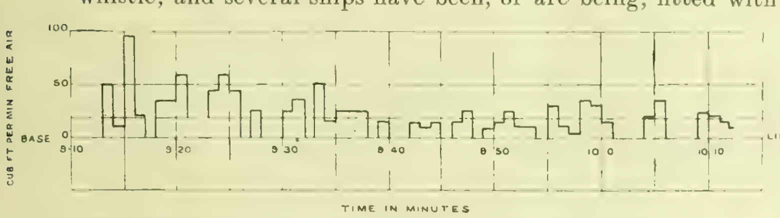


FIG. 2.—DIAGRAM SHOWING MAXIMUM EQUIVALENT AMOUNT OF FREE AIR REQUIRED TO OPERATE STEERING ENGINES. OBSERVATIONS TAKEN ON BOARD S.S. "DEUTSCHLAND" ON THE VOYAGE TO NEW YORK, APRIL 10th, 1911.

means for supplying compressed air for this purpose, so that, on leaving port, the donkey engine may be shut down.

Numerous figures have been obtained by the author in order to ascertain the probable air consumption of a steering engine of the ordinary steam type usually used, and, as might be expected, it was found that when a ship is on her course at sea, the quantity of air required for steering is very much less than that which is required when a ship is being navigated in crowded waters up to her berth. When steam, however, is used for auxiliaries, this power can be retained until the ship is at sea, when the donkey boiler may be shut down and air instead of steam used for steering. If steam is not used for auxiliaries, the provision to be made for navigating narrow waters is discussed later.

The basis on which the author has computed the amount of air required for steering has been to ascertain the cubic contents of the steering engine cylinders per revolution, to note the pressure required to throw the helm hard over when the ship is running at full speed, and from these figures to ascertain the equivalent quantity of free air at atmospheric pressure which would be required per revolution. All that is required then is to note the varying revolutions made by the steering engine as the conditions vary from minute to minute during any particular trial, when not only can the maximum and the minimum demands for air be ascertained, but the average quantity which is needed. From these figures the size of the compressor and the capacity of the storage reservoirs can be determined.

Fig. 1 shows a diagram in which the fluctuations in the air required from minute to minute are shown, these being plotted from figures taken on the trial trip of the s.s. "Berwindvale," through the courtesy of Messrs. Raylton, Dixon, and Co. The ship is 405ft. long, 54·2ft. beam, and has engines of 3,200 i.h.p. and a speed of 12 knots. The effect of the rapid movement of the helm when the ship is turning when entering and leaving the measured mile is clearly shown, together with the steady running on the mile. The demand for air when turning is at a very high rate, but, on the other hand, the period of this large demand is very short.

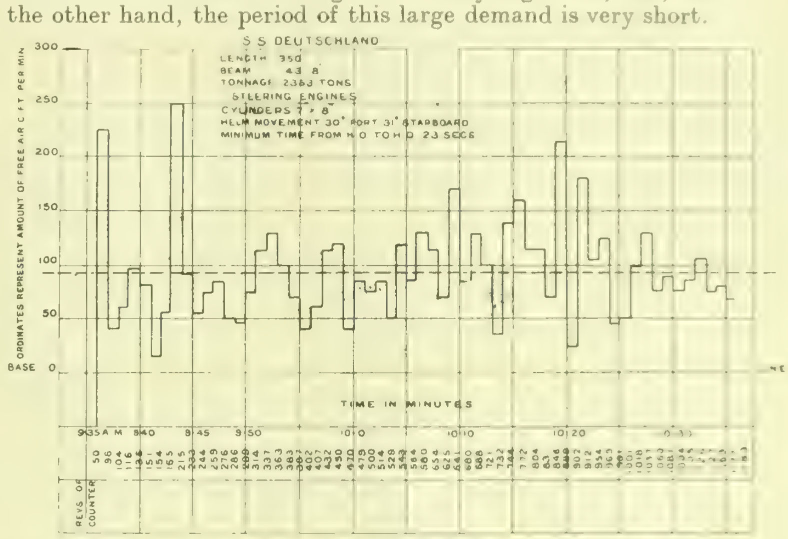


FIG. 3.—DIAGRAM SHOWING MAXIMUM EQUIVALENT AMOUNT OF FREE AIR REQUIRED TO OPERATE STEERING ENGINES. OBSERVATIONS TAKEN ON BOARD S.S. "DEUTSCHLAND" ON THE VOYAGE TO NEW YORK APRIL 6th, 1911

Attention is particularly drawn to the average air which would be required for a steering engine on a ship of this size when on her course after her trials, as shown between the hours of 1-10 p.m. and 2-30 p.m. on the diagram, when the average air consumption for this period is only 20 cub. ft. free air per minute.

One of the companies for whom the author's firm has designed a compressed-air steering equipment is that of the Reiherstieg Schiffswerfte und Maschinenfabrik, of Hamburg, who, it is well known, have completed a Carels-Diesel engine of about 2,000 h.p. In order to obtain precise results, this firm kindly arranged with the owners of the ship for exact particulars to be taken each day on a sister ship making a voyage to and from America, and equipped with steam engines and boilers, and therefore having steam steering gear. Complete records were taken of the revolutions of the steering engine during one watch each day on both the westward and eastward course. Fig. 2 shows one of these diagrams taken under the best conditions of wind and sea, while Fig. 3 shows a similar diagram plotted from observations taken during stormy weather. These are considered to represent the maximum and minimum conditions. As a result the design of steering compressor shown on Fig. 4 was constructed for their ship.

A steering equipment on these lines is successfully at work on the M.S. "Rolandseck," with Diesel engines by Messrs. Joh. C. Tecklenborg A.-G., of Geestemunde, and the results

* Paper read at the spring meetings of the fifty-fourth session of the Institution of Naval Architects, March 13th, 1913.

at sea show that under the worst conditions there is ample air for steering. The steering compressor is of a double-pressure type, and is of simple construction, and arranged to be driven by levers from the main engine, as shown on the illustration. Most of the air compressed and delivered by this compressor is supplied at the normal pressure which would be used by a steering engine if steam driven. The air is supplied to a reservoir A, and from thence to the steering gear. The remainder of the air is compressed to a much

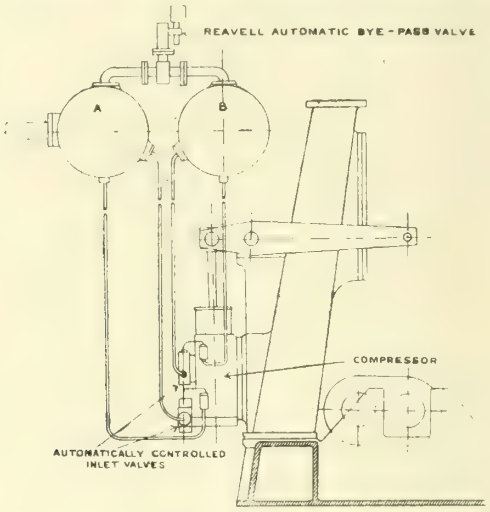


FIG. 4. DIAGRAMMATIC ARRANGEMENT OF REAVELL STEERING COMPRESSOR AND AIR RESERVOIRS.

higher pressure, and delivered into reservoir B, which holds it as stored air for an emergency.

The valves for both the low-pressure and high-pressure air are controlled from the receivers A and B in such a manner that if both of these receivers are filled to their desired pressure the compressor is unloaded and throws no work upon the engine at all. With a system like this the compressor may be generously proportioned so as to be of ample size, even in heavy weather, because, under favourable conditions, it will run unloaded for most of its time. Circumstances might arise, however, where, *e.g.*, with the ship going at half-speed in fog or ice, the helm is required to be thrown hard over once or twice in quick succession. It is for an emergency such as this that the high-pressure storage air reservoir is provided.

A specially constructed and automatically controlled valve is fitted on or between the two reservoirs, and is controlled by the pressure in A. When this pressure falls below a predetermined figure, the stored air passes from B into A to supplement that supplied by the low-pressure portion of the compressor, and the compressor at once begins to supply air at the high pressure also in order to replenish the high-pressure receiver B.

The use of low-pressure air from the 3-stage compressor on the marine engine itself has been suggested for steering gear, instead of an independent compressor, and by the courtesy of Messrs. Furness, Withy, & Co. the author is able to state that on the M.S. "Eavestone," with Carels-Diesel engines, the surplus air supplied by the Reavell 3-stage compressor has been successfully used instead of steam in the steering gear of that ship on two complete voyages. This, of course, is only possible where the 3-stage compressor, from the dictates of safety, has been made unduly large, and for several reasons, which it is beyond the scope of this paper to discuss, it is much more economical to construct the main 3-stage compressor of proper size for this work and to supply a properly constructed steering compressor, with its reservoirs, for steering, rather than to run the risk of prejudicially affecting the proper operation of the main compressor, which has such an important function to perform in the Diesel engine.

Cargo Work.—Compressed air having been demonstrated to be so simple and suitable for steering purposes, it follows that the donkey boiler is being carried permanently in the ship simply for the operation of the winches when in port, because, in an ordinary cargo boat, if the winches are successfully dealt with by another motive power, there is no other purpose for which steam is now used which cannot be served by another power. The author's attention has for some time been directed, therefore, to the determination of the actual conditions under which deck winches operate, so as to find the conditions under which air can be most efficiently substituted for steam.

The results of these investigations, which are given hereafter, show clearly that a different understanding is required between the shipowner, the shipbuilder, and the engineer before air can be successfully used. The author recollects investigating closely the compressed air equipment demanded to fulfil the requirements of a specification sent to his firm for an earlier Diesel-engine ship. It was demanded that the winches—eight in number—should be capable of simultaneously lifting their maximum load of 5 tons at 80ft. per minute with a pressure of 100lbs. per square inch of compressed air. The resultant compressor calculated from this data was of such a size that it required an engine nearly half the size of the main propelling engine in the ship to drive it.

The author then commenced a series of investigations to ascertain the exact conditions under which in an ordinary cargo or coasting steamer the 3-ton or 5-ton winches operated. These investigations showed that 5-ton winches do not normally lift 5 tons at 80ft. per minute; that the pressures usually found in the cylinders of winches are far less than 80lbs. per square inch; that all of the winches do not always work together; that the portion of the complete cycle of the operation of a winch during which work is being performed is relatively small. For example, in hoisting bales of goods from a hold to the quay the demand for steam is practically limited to hoisting, while the operation of slewing, lowering, hoisting the empty hook, slewing and lowering to hold required practically no power.

Under these conditions it will be readily seen that with sound engineering co-operation between the shipowner, shipbuilder, and engineer, a compressed-air plant of relatively small size can be used and will be sufficient. Opportunities were given to the author, through the courtesy of Mr. Roxburgh, of the Powell Line, to take complete figures of the unloading of a coasting steamer, the "Norfolk Coast," in the port of Ipswich and at Liverpool. The winches were of the Wilson chain-driven type. Table I. shows the result of these investigations in Ipswich Docks.

Dealing with the cycle, it will be observed that the average complete cycle of one winch occupied 87½ secs., while out of this period the lifting operation occupied only 17·2 secs., or only one-fifth of the total cycle. It will also be observed that the average weight of the bales did not exceed 6½ cwts. The most interesting part of these investigations, however, relates to the pressure actually required to operate the winch freely under these conditions. There was a pressure in the deck pipes of 90lbs. per square inch, and a low reading pressure gauge was attached directly to the steam chest of the winch, and the stop valve on the winch adjusted so as just to give a sufficient flow of steam to enable the winch to run freely to the satisfaction of the stevedore. The maximum pressure observed during the whole of the investigations

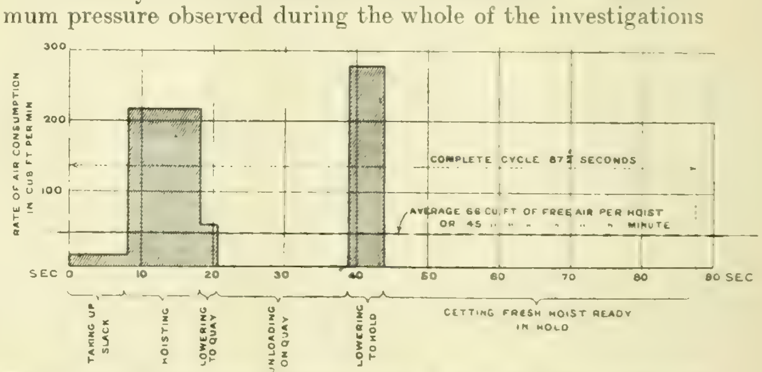


FIG. 5. OBSERVATIONS TAKEN AT IPSWICH DOCKS ON BOARD S.S. "NORFOLK COAST."

did not exceed 16lbs., and the average pressure was about 10lbs. per square inch. The average pressure during unloading of the same vessel at Liverpool was 12lbs., the average weight of the goods being slightly greater. Fig. 5 shows in diagrammatic form the maximum and minimum demands for air in a winch operating under these conditions, and with suitable air reservoirs and pressure control shows also what would be the average air to be supplied by the compressor.

By the courtesy of Mr. Adams, of the Shaw-Savill Line, a number of observations were taken on the s.s. "Rangatira," fitted with 12 "Wilson" winches. Accurate figures

were obtained from the performance of one winch to obtain the maximum and minimum pressures and average time cycles, while the average loads lifted by the other winches were noted. The average weight of load lifted was found to be approximately 12 cwts., with an average cycle of two minutes, and the heaviest lift observed during the day was 30 cwts. With this load a pressure of 20lbs. was sufficient to lift it slowly, and 40lbs. to lift rapidly. The pressure required to lift the average load at full speed was 20lbs. The average time of actual lifting was 10 secs., giving a ratio to total average cycle of 2 minutes of 1 to 12. A calculation based on these observations shows that in a vessel of this size and power (5,000 h.p.) the engine of the auxiliary or manœuvring compressor, if the ship were equipped with Diesel engines, would be amply able to drive in port a compressor arranged to operate the deck winches with compressed air on this low-pressure basis.

TABLE I.—*Observations made on s.s. "Norfolk Coast" at Ipswich.*

Winch, port side of fore hatch.

Hoisting. Taking up slack.	Hoisting. Raising.	Hoisting. Total.	Lowering to hold.	Total time complete cycle.		Total Weight.
sec.	sec.	sec.	sec.	min.	sec.	cwts.
4	12	16	5 approx.	0	55	7
6	10	16	,,	1	39	3
6	10	16	,,	1	42	7
15	11	26	,,	1	8	7½
7	7	14	,,	1	55	7½
12	6	18	,,	1	18	7½
5	9	14	,,	1	21	8
7	7	14	,,	1	36	3½
5	9	14	,,	1	29	8
16	12	28	,,	1	29	7½
2	12	14	,,	0	41	5
13	11	24	,,	2	6	7½
8	7	15	,,	1	7	3½
4	9	13	,,	1	32	9
5	10	15	,,	1	11	4
7	7	14	,,	2	7	9
15	12	27	,,	1	22	7½
8	12	20	,,	1	28	8
5	12	17	,,	1	43	3½
5	10	15	,,	1	15	8
4	8	12	,,	1	17	3½
10	11	21	,,	1	45	7½
2 min. 49 sec.	3 min. 34 sec.	6 min. 23 sec.	—	32	6	142½
Avge 7·7 secs	9·7 secs.	17·2 secs. At rate of 13·6 tons per hour.	—	1	27½	6½

Average steam pressure, 10lbs.

By the courtesy of Messrs. R. & W. Paul, Ltd., of Ipswich, the author has been enabled to take accurate observations of the performance of steam winches when whipping grain cargoes in Ipswich docks. Two ships, the s.s. "Blackfriar Gate" and the s.s. "Brookby," were selected, each of approximately 5,000 tons cargo capacity, and having five cargo holds, dealt with by five winches built by Messrs. Clarke, Chapman, & Co., the winches being 7 by 10. The pressures were observed in the same manner as heretofore, and when whipping two sacks, each of 240lbs., or a total of 4¼ cwts., at an average speed of 300 revs. per minute, corresponding to about 120ft. per minute hoisting speed, the average steam pressure observed in the steam chest of the winch was between 16lbs. and 20lbs. per square inch.

Other observations taken on other vessels, with a pressure gauge fitted directly on to the winch cylinders in each case, show that the steam pressure actually used in the normal working of the winches, whether lifting bales of goods or whipping grain or dealing with other cargoes, is very much less than the specification of 80lbs. or 100lbs. usually asked for. Further, the largest percentage of goods carried, say, by a coasting steamer or a passenger and cargo steamer, or any general cargo boat dealing with other than grain or coal cargoes, are of much less weight than the maximum for which the winch is constructed. It follows, therefore, that they can be dealt with at a correspondingly low pressure in the winch cylinders. It only remains to consider, if a lower pressure is used with air, what should be done in the small percentage of cases where a heavy lift is required. An investigation into this has shown that a heavy lift is usually of an irregular shape, which cannot be efficiently dealt with at a high rate of speed, such as 80ft. or 100ft. per minute in an ordinary cargo boat, so that with suitably arranged back gear in the winch these heavy loads when required can be also lifted with a low pressure of air.

At this juncture, therefore, the author would point out that the conditions of air-operated winches differ entirely from steam winches from this point of view of pressure. Indeed, the steam analogy is a false one when applied to air problems. Further, paradoxical as it may seem, the best overall efficiencies with air can be shown to be obtainable, other things being equal, when the pressure is low rather than when the pressure is high. When once the latent heat of the water is overcome and steam is produced, the extra cost of raising that steam to a pressure of 100lbs. per square inch is negligible. With air, however, every pound of extra pressure which is desired has to be first put into the air in the air compressor at the expenditure of an equivalent amount of power in the motor driving it. Hence it is that earlier attempts to deal with cargo problems on the old lines with compressed air have been wasteful, and the above are the lines on which it is possible to economically operate deck winches by air pressure.

A reference to Fig. 6 will illustrate this point. In the two diagrams there given, one shows the diagram resulting

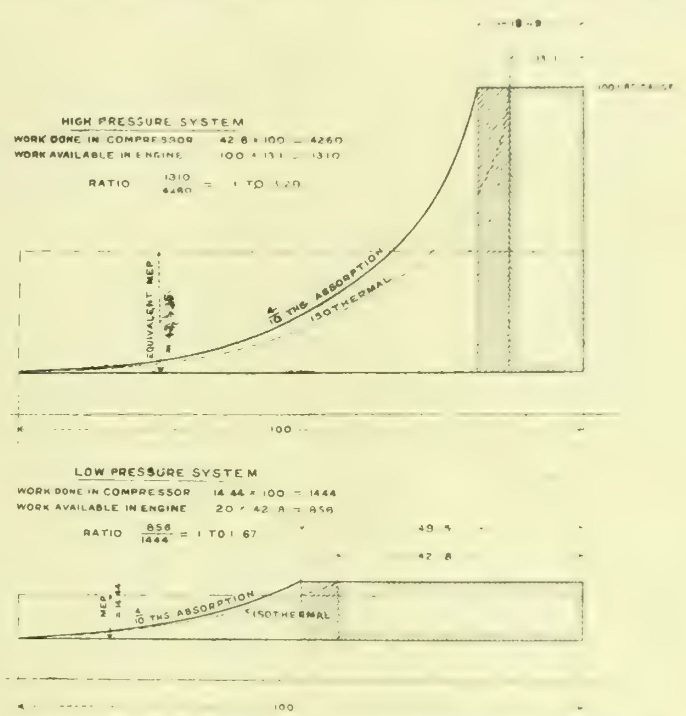


FIG. 6.—DIAGRAM SHOWING ENERGY AVAILABLE FOR WORK COMPARED WITH ENERGY NEEDED FOR COMPRESSION.

from the compression of air in one stage to 100lbs. pressure, assuming an absorption of four-tenths of the heat of compression; the other shows the resulting diagram when compressing to 20lbs. pressure under the same conditions. If the air, when compressed, is to be used in a deck winch, the remaining heat of compression (in hatched lines on diagram) which is found in the delivered air will have been lost in the receiver, and the air will pass to the winches practically cold. The shaded portion, therefore, shows that amount of the diagram which represents the compressed air which can be used in the winch.

For the high-pressure system it will be seen that the ratio of the available energy in the air to the work done upon the air in the compressor, excluding mechanical loss, is as 1 to 3·28. With the 20lbs. pressure diagram, however, the ratio of the work available to the work done on the air is as 1 to 1·67. In other words, the efficiency expressed in these terms of the low-pressure system compared to the high is as 2 to 1 under the above conditions of pressure. As to the power required, the diagram shows that three times the energy is needed to compress the air to 100lbs. as compared with that required for 20lbs. If, therefore, it is accepted that the lower pressures here dealt with are sufficient, it

will be seen that the Diesel or semi-Diesel engine used for driving the auxiliary compressor can at once be reduced to one-third the power which will be required if the air is compressed to 100lbs. The next point to observe is that the quantity of free air required to fill the cylinders of a winch at 100lbs. pressure is more than three times as great as that required to fill the cylinders to 20lbs. pressure, so that the compressor required will be one-third of the size, and the

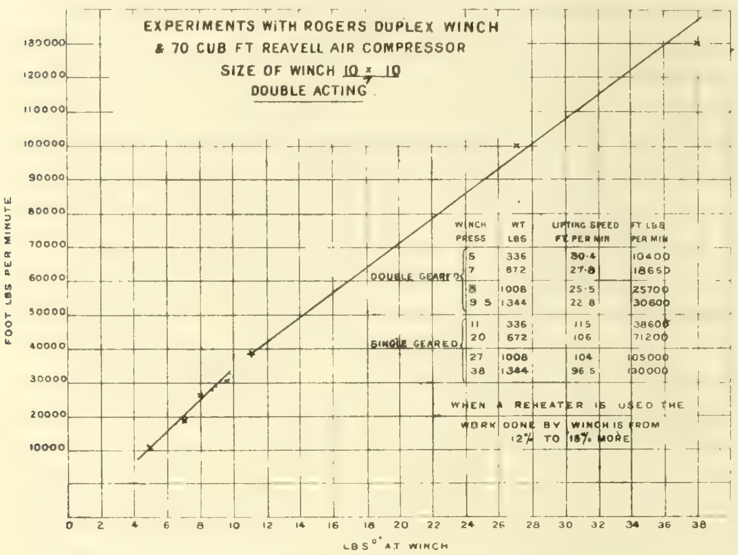


Fig. 7.

power required to drive it will again be reduced to one-third, or one-ninth of what would be required for the larger machine at 100lbs. pressure.

The calculations given, which are based on a pressure of 20lbs., are not to be taken as an absolute recommendation, although the experiments made indicate that pressures lower even than these are actually found in practice to be used. They serve rather as a guide to the direction in which economy must be sought for in the installation of compressed air for auxiliaries, but naturally the selection of the proper pressure to use must depend in each case upon investigations based upon the requirements of the particular ship until further experience has been accumulated.

Air Reheating.—The diagram on Fig. 7 gives the result of a series of experiments carried out at the author's works on a 3-ton winch, having cylinders 7in. by 10in., kindly supplied for the purpose of these trials by Messrs. Robt. Roger & Co., Ltd., of Stockton-on-Tees. The intention of these experiments was to ascertain the increased efficiency obtainable by heating the delivered air by means of the exhaust from an oil engine.

Fig. 8 shows the general appearance of the testing plant, consisting of a Reavell 2-cylinder paraffin engine driving a Reavell quadruplex compressor. The exhaust gases from the engine were passed through the tubes of the reheater shown, while the body of the reheater was used as an air reservoir and from it the heated air was passed to the winch. The average figures obtained show that when working under conditions given on Fig. 7 with the Rogers winch, the increased speed at which the winch operated with a fixed speed of the air compressor and oil engine varied from 12 per cent. to 15 per cent. When the air, however, was carried for a long distance and brought back to the winch, so as to imitate the conditions which would happen on the deck of a ship, most of this heat disappeared.

The conclusion arrived at was that unless the air could be used immediately after leaving the reheater and without passing through a long range of pipes, the extra expenditure for reheating was not recouped. The provisions made by the author for testing the Roger winch included a derrick to represent the average height from the hold of a ship to overside, and provisions were made for lifting weights of varying amounts from 3 cwts. to 12 cwts., both in single and double gear. The results of these tests confirm the results already given earlier in this paper. The only criticism which can be fairly levelled at the low-pressure system is that the proportion of the total energy in the compressed air which is uselessly absorbed in friction in the deck winch is greater than when a high pressure is used.

On the other hand, the leakages which at present are frequently observed in the working of ordinary deck machinery at the usual steam pressures carried, will be enormously reduced with a lower air pressure, and may be taken as a set-off against this loss. Moreover, it must be remembered that in ordinary deck winches no high steam economy is aimed at. The period of cut-off is very near the end of the stroke and consequently there is scarcely any expansion.

Advantages of Low-pressure Air System.—These conditions are ideal, however, for low-pressure air, because if no expansion is attempted there can be no difficulties as to freezing in the exhaust, which is sometimes a difficulty when high-pressure air is used and expanded. All refinements as to reheating are unnecessary with a low-pressure system. A single uncovered pipe is all that is necessary from the air reservoir to the deck winches. No return pipe is needed, and the winch can exhaust freely into the atmosphere. and undoubtedly thereby increase its efficiency slightly, as compared with the exhaust pipes discharging overside, which are familiar in ordinary cargo boats with steam winches. No difficulties as to condensation will occur, and the general formation of the winch so familiar to seamen and dock hands all over the world can be retained. The cost, therefore, of a pneumatic deck equipment on these lines may be expected to compare very favourably with any scheme of hydraulic or electric deck winches for Diesel-engined ships.

Probably the only modifications which would be required to standard winches would be directed towards improving the efficiencies and reducing the leakage losses, and if the experience in constructing compressed air machinery is followed these modifications could be readily effected. The author would point out that in these investigations he has principally had in view the type of cargo boat in which the Diesel engine is at present being developed, and which would also probably be the type of boat selected for any experiments with suction gas in gas engines, for which, of course, this pneumatic system would be equally applicable.

The remainder of the auxiliary machinery in such boats could all be operated directly from the main engines, or could be worked by compressed air. A donkey pump or ballast pump, for example, as is well known in mining work, can be just as satisfactorily operated with air as with steam. When passenger boats, and cargo boats also carrying passengers, are considered, there is undoubtedly more to be said for the

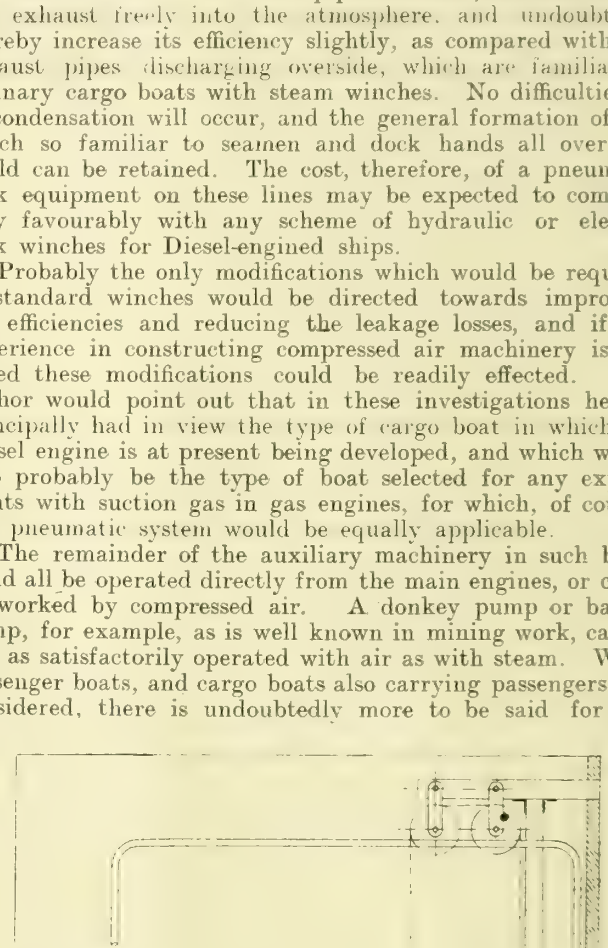


Fig. 8.—Arrangement of Testing Plant for Ascertaining Air Consumption of Roger's Winch.

considerable use of electricity for auxiliaries, although the author believes that, if investigated on correct lines, compressed air will even in these cases be found to be a most useful, efficient, and economical servant. The author claims, however, that for the class of ship which this paper principally deals with, the case for compressed air is an exceedingly strong one when approached on the principles he has ventured to lay down as the result of his investigations.

The engine-room of a Diesel-engined cargo boat using compressed air for the winches, windlass, &c., would therefore be equipped as follows: The compressor for supplying high-pressure air to the main engines would be made of just the size required for that purpose, without allowing margins for auxiliary purposes. The duplex steering system from levers on the engine would provide compressed air for steering; and the usual pumps for ballast, water circulation, &c., would also be driven by these levers, or the scavenging pump levers if the engine is of the 2-stroke cycle type. There would be an auxiliary Diesel, or semi-Diesel engine, which would have compressors attached to each end of its crank shaft. On the one end would be the high-pressure auxiliary or manœuvring compressor, to be used when starting and also navigating the ship in crowded waters, so as to supplement the air supply from the main compressor when the engine is going dead slow or is stopped. The air from this compressor would also be used to increase the air available for steering purposes and the delivery from the compressor would be automatically controlled by pressure regulators, so that no attention would be required beyond lubrication.

The other compressor would be of the low-pressure type for dealing with winches and windlasses; and the two compressors would be connected to the auxiliary engine by clutches or other simple and suitable means, so that when the ship is under way the low-pressure compressor can be disengaged, and when the ship reaches port and is about to deal with her cargo, the high-pressure auxiliary compressor can be disengaged and the low-pressure compressor connected up.

There would doubtless be other practical details to deal with (such as the heating of the officers' quarters, which could be dealt with by a hot-water circulating system instead of a steam system, the heat being obtained from the exhaust of the Diesel engine at sea and the auxiliary Diesel in dock), but the author ventures to think that on its broad lines a good case has been made for the use of compressed air for auxiliary machinery.

PRACTICAL HEAT TREATMENT OF ADMIRALTY GUN-METAL.*

BY H. S. PRIMROSE AND J. S. G. PRIMROSE,

In his paper to the Institute on a former occasion,† one of the authors made the suggestion that if gun-metal were subjected to heat treatment, such as quenching and annealing at various temperatures, profound changes would be found to take place in the properties of the metal. Since then this joint research has been undertaken with the object of finding a simple and reliable method of improving Admiralty gun-metal so as to obtain the highest possible tensile strength without reducing the percentage elongation, and at the same time imparting to it a greater soundness and homogeneity of structure.

So far as the authors are aware, no previous work has been published dealing with this subject as applied to the most commonly used industrial alloy known as Admiralty gun-metal, of which the specification is 88 per cent. of copper, 10 per cent. of tin, and not more than 2 per cent. of zinc, with a maximum variation of 1 per cent. of any of its component metals. This composition is readily obtained in practice which is under proper metallurgical control, but even when the analysis closely agrees with the specification it is sometimes difficult to produce castings which fulfil the requisite physical tests attaining a tensile strength of 14 tons per square inch, and an elongation of 7·5 per cent. on a 2in. test bar. Many practical founders and some experimenters have experienced considerable trouble in making sound castings with this alloy to stand a high water-pressure; and undoubtedly the internal structure of the metal has a great deal to with this important property, as well as with the other characteristics.

Although blow-holes are the commonest known source of unsoundness in gun-metal, these may be entirely absent and still the castings are not completely satisfactory when submitted to the physical tests and hydraulic pressure, owing to the imperfect arrangement of the constituents. Even when the physical tests are complied with and the structure under the microscope is of the interlocking design with uniformly intermixing primary crystallites and inter-spacial eutectic, the metal as cast may fail under water pressure owing to the water sweating through the microscopical pores formed between the two constituents. These constituents are of widely different chemical composition, and possess different coefficients of contraction.

When ordinary gun-metal is cast and slowly cooled, the first portions to solidify consist of primary crystallites of the α-constituent, which is copper containing all the zinc and only a small quantity of tin in solution in it. As the crystals continue growing and the temperature falls, an increasing amount of tin is held in solution by the solidifying α-constituent, and at the moment of solidification the interspaces are filled with the β-constituent, which is copper containing still more tin in solution. As this β-solution is only stable through a short range of temperature, on cooling it undergoes decomposition with the formation of the eutectic containing the δ-constituent, Cu_4Sn; and the dark-etching, littoral zones of secondary α-constituent. It is between these two latter constituents that the microscopic crevices occur, and they are so small that the fractured surface does not reveal their presence. It might appear possible to produce gun-metal castings in which the eutectic areas were so small and uniformly distributed that they would not be in a connected meshwork throughout the mass. Chilling the metal in the mould has this effect by preventing the decomposition of the β-constituent, but in actual practice it is not possible to so control the rate of solidification and cooling that the eutectic segregations are always prevented from arranging themselves in a harmful way.

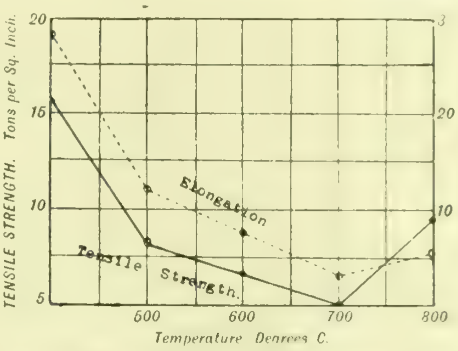


FIG. 1. INFLUENCE OF QUENCHING TEMPERATURE. SERIES "E," GRAPH OF TABLE I.

Method of Procedure.—In carrying out the tests it was deemed advisable to adhere to the customary "inch-round" bars 10in. long, which were cast from gun-metal at a temperature just below 1,100° C., both into dry-sand moulds and chills, with the object of producing either slow or rapid solidification as desired. The rate of cooling was dependent upon the arrangement of the boxes, and was moderately slow for dry-sand castings, comparatively quick for chills alone, and very slow when the metal was cast in chills placed in close proximity to and in connection with a large body of metal cast at the same time. Two sets of duplicate bars were used in all cases, and these were prepared for testing and after-treatment, by turning the central portion down to a diameter of ⅝in., giving a cross-sectional area 0·306 sq. in over a suitable length for a 2in. test piece.

In the tensile testing machine employed, only the ultimate breaking strain was taken. The elongation was also determined. The average value of the results from the four bars have been tabulated, correct to the first decimal place. In none of the tests recorded did the tensile strength vary by more than 1 per cent. and the elongation by 5 per cent. between maximum and minimum.

In performing the experimental tests of heat treatment the bars were heated gradually to the required temperature in a Heraeus electric resistance furnace, thus minimising the oxidation of the metal; and no appreciable loss of zinc was noticed even at the higher temperatures. The bars were maintained for a definite time at the fixed temperature as determined accurately by a pyrometer, and then either quenched in water or cooled off in the furnace, which took about two hours to attain normal temperature. The test bars were not subsequently dressed or burnished, as this was found to interfere with the physical condition of the bar;

* Abstract of paper read before the Institute of Metals, March, 1913.
† "Metallography as an Aid to the Brassfounder," by H. S. Primrose, "Journal of the Institute of Metals," No. 2, 1910. Vol. IV.

burnishing especially imparted a skin to the metal which materially raised the tensile strength. Sections were cut from each bar, and after having been polished on the transverse cut and etched in the usual way with ferric chloride, they were examined microscopically and typical structures

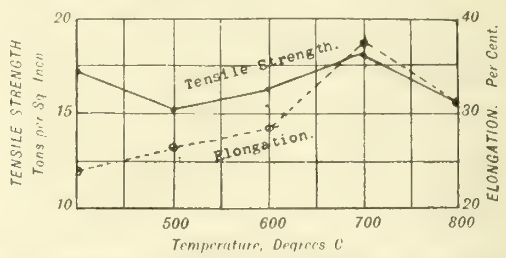


FIG. 2. INFLUENCE OF ANNEALING TEMPERATURE. SERIES "F," GRAPH OF TABLE II.

were photographed. The plan adopted in marking the specimens was as follows:—

First letter.—Series of the tests: E.F.G.H.K.

Second letter.—Method of casting: In dry-sand (D.), in chills (C.).

Third letter.—Heat treatment: Annealed (A.); normal as cast (N.); quenched (Q.).

First figure.—Temperature of heating: 500° C. (5), 600° C. (6), 650° C. (6½).

Second figure.—Time of annealing: 5 mins. (V.), 10 mins. (X.) (if not stated), 30 mins. (XXX.).

Quenching.—In view of the excellent results obtained by Guillet* on quenching pure bronzes of various composition, from temperatures between 600° C. and 700° C., it was thought that gun-metal would also show an increase in the strength and the elongation if similarly treated. This, however, was not found to be the case, as there was a considerable reduction in the values got on tensile testing, and evidently the presence of the small proportion of zinc exercises a profound influence on the character of the metal. Thus in Series "E," in which the test bars were cast in dry-sand moulds at a moderate temperature of about 1,060° C., ensuring both slow solidification and slow cooling, and then heated slowly (after turning to size) to temperatures ranging from 500° C. to 800° C. before quenching, the physical properties were very considerably poorer than that of the normal cast bars. This is shown in Table I., the values of which are given graphically in Fig. 1.

It is noteworthy that the elongation falls off consistently with the rise of quenching temperature, and also that it follows the drop in tensile strength almost proportionately. The lowest values are got with the quenching temperature of 700° C., when the tensile strength is only about one-third that of the normal bars, and the elongation about one-ninth. From this and subsequent tests it is evident that there must be some radical change in the constitution of the alloy in the vicinity of this temperature.

Reheating and quenching gun-metal castings does not effect any improvement, even if this were possible without

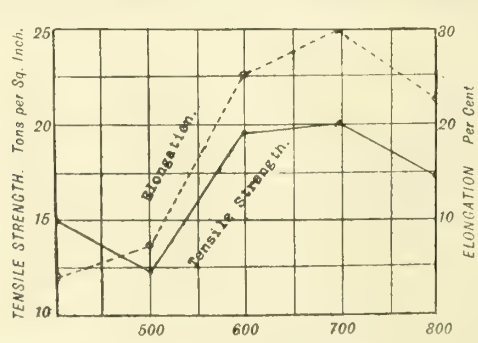


FIG. 3.—INFLUENCE OF ANNEALING TEMPERATURE. SERIES "G." GRAPH OF TABLE III.

damaging the shape of the casting. In practice it is not feasible to quench the metal immediately after it has solidified, although this may have been done with test bars which were quenched direct, without having been first cooled to the ordinary temperature, and then reheated, as were the bars tested in this series.

Annealing.—The simple operation of annealing was next tried upon sets of test bars which were cast and cooled in a variety of ways. The annealing consisted of a gradual heating up to various temperatures, at which they were maintained for various periods of time. The subsequent cooling in each case was moderately rapid until 400° was attained, after which it was comparatively slow.

TABLE I.—*Influence of Quenching Temperature on Dry-sand Castings.*

Mark.	Quenched from Degrees C.	Tensile Strength. Tons per Sq. In.	Elongation per cent.
E.D.N.		15·6	28·0
E.D.Q. 5	500	8·2	12·0
E.D.Q. 6	600	6·5	7·5
E.D.Q. 7	700	4·9	3·0
E.D.Q. 8	800	9·0	5·5

Series "F."—In this series the bars were cast in dry-sand moulds with the same metal and from the same temperature as Series "E." This treatment produced a slow solidification of the metal, followed by a moderately slow cooling. This is the general type to which most gun-metal castings belong, and it is of interest to note that the subsequent heat treatment effected a most remarkable improvement in the elongation of the specimens, without in any way diminishing the

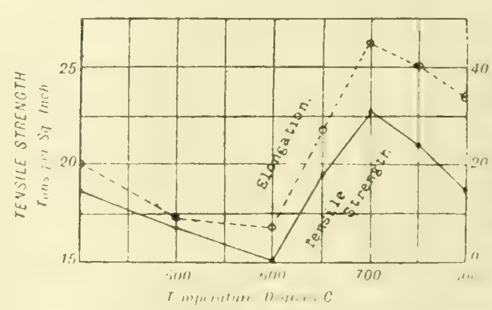


FIG. 4.—INFLUENCE OF ANNEALING TEMPERATURE. SERIES "H." GRAPH OF TABLE IV.

tensile strength of the material. Table II. gives the average results of the tensile testing, and these are represented in graph form in Fig. 2. Whilst the ultimate breaking strain of the metal is slightly increased as the annealing temperature rises to 700°, it falls off most remarkably at 800°. The elongation is very considerably increased up to the temperature of 700°, after which it also falls away.

TABLE II.—*Influence of Annealing Temperature on Dry-sand Castings.*

Mark.	Annealed at Degrees C.	Time. Mins.	Tensile Strength. Tons per Sq. In.	Elongation per cent.
F.D.N.		—	17·2	24·0
F.D.A. 5........	500	30	15·1	26·5
F.D.A. 6........	600	30	16·3	28·5
F.D.A. 7........	700	30	18·0	37·5
F.D.A. 8........	800	30	15·5	31·0

Series "G."—The bars of this set were cast in chills of solid metal, so that both the solidification and the cooling were rapid. In this case the annealing again produced a remarkable increase in the elongation, and this was attended by an almost equally striking increase in the tensile strength. The maximum results were again obtained by the annealing at 700° for 30 mins., and lower results were got with bars heated to a point both above and below this temperature. Table III. and Fig. 3 give the average results obtained in the tests.

Series "H."—In this and the following series "K," the bars were cast in chills in close proximity to a large body of metal which was cast and cooled along with them, so that

* L. Guillet, "Quenching of Bronze," "Revue de Metallurgie," February, 1905

although their solidification was fairly rapid, the cooling afterwards was comparatively slow. The very great increase

TABLE III.—*Influence of Annealing Temperature on Chilled Castings.*

Mark.	Annealed at Degrees C.	Time. Mins.	Tensile Strength. Tons per Sq. In.	Elongation per cent.
G.C.N.	-		15·0	4·0
G.C.A. 5	500	30	12·3	7·5
G.C.A. 6	600	30	19·6	25·0
G.C.A. 7	700	30	20·0	30·0
G.C.A. 8	800	30	17·2	22·5

in both the tensile strength and the elongation got by annealing for half an hour at 700° is again evident from Table IV.

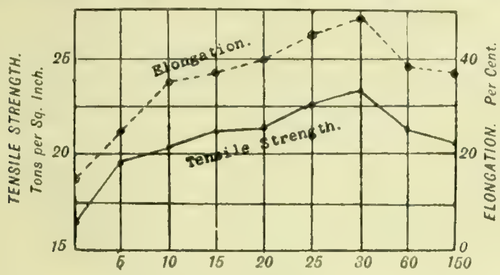


FIG. 5.—INFLUENCE OF TIME OF ANNEALING AT 700° C. SERIES "K," GRAPH OF TABLE V.

and Fig. 4, showing the average results obtained in testing. Intermediate points at 650° and 750° were taken, but in each case the results were inferior to those obtained at 700°.

TABLE IV.—*Influence of Annealing Temperature on Chilled Castings.*

Mark.	Annealed at Degrees C.	Time. Mins.	Tensile Strength. Tons per Sq. In.	Elongation per cent.
H.C.N.	—	—	18·6	20·0
H.C.A. 5........	500	30	16·7	9·0
H.C.A. 6........	600	30	15·0	7·0
H.C.A. 6½	650	30	19·5	27·0
H.C.A. 7........	700	30	22·5	45·0
H.C.A. 7½	750	30	21·0	40·0
H.C.A. 8........	800	30	18·6	34·0

Series "K."—The tests in this series were carried out with the object of determining the range of time during which the heating should be continued in order to get the best results when annealing was done at the correct temperature of 700°. This is naturally dependent upon the thickness of the metal under treatment, but for the size of test bars used (⅝in. diam.) this was shown to be somewhere about 30 mins., as seen from the results tabulated in Table V. and shown graphically in Fig. 5. The annealing for this period shows the maximum results both in tensile strength and elongation, but the increase is only slight after annealing has been carried on for 20 mins. Very long continued annealing produces a slight diminution in the strength and elongation, but it is evident that if the right temperature of 700° be attained the time of annealing at this temperature may be varied within fairly wide limits without impairing the improvement effected in the structure and character of the metal.

TABLE V.—*Influence of Time of Annealing on Chilled Castings.*

Mark.	Annealed at Degrees C.	Time. Mins.	Tensile Strength. Tons per Sq. In.	Elongation per cent.
K.C.N.	—	—	16·5	15·0
K.C.A. V.	700	5	19·6	25·0
K.C.A. X.	700	10	20·4	35·0
K.C.A. XV.	700	15	21·2	37·0
K.C.A. XX.	700	20	21·4	40·0
K.C.A. XXV. ..	700	25	22·5	45·0
K.C.A. XXX. ..	700	30	23·1	48·5
K.C.A. LX.....	700	60	21·2	39·5
K.C.A. CL.....	700	150	20·5	37·0

Thermal Analysis.—The cooling of the metal from fusion is shown at (*a*) in Fig. 6 as an inverse rate curve, and represents the halt points as only very slightly different from those of the corresponding bronze in the freezing-point diagram of Shepherd and Blough, a portion of which is reproduced for comparison. The heating curve shows that the reverse changes are not accompanied by very large absorptions of heat, as evinced by the curve (*b*), Fig. 6. The halt below 700° evidently marks the completion of the δ to β change. The inverse rate curve (*c*), Fig. 6, shows the cooling of the metal after annealing for 60 mins. at 800°, and indicates that although the β inversion still exists, there has been a considerable diminution of the δ change, as would be expected from the examination of the microstructure of the metal after annealing at this temperature.

Practical Applications.—The importance of the annealing of gun-metal castings, which in service have to stand severe tests, must be abundantly evident from the foregoing results. One great advantage it possesses lies in making the metal capable of complying with the most stringent specification as regards tensile strength and elongation, although it must be clearly pointed out that it cannot be regarded as "faking" the metal. Such metal as may be defective due to the presence of gas or blow-holes is not materially improved by the heat treatment; but when slight defects arise, due to the harmful segregation of the eutectic structure, then this is completely removed by the proper annealing.

One of the most frequent tests now applied to important gun-metal castings is that of water pressure, and in many cases they fail most dismally under even moderate pressure. The metal is thus condemned as bad, whereas it is really quite good, and it is only a strange characteristic of the metal possessing the wrong arrangement of its constituents which makes it unsuitable for this purpose when cast and not further heat-treated as suggested in this paper.

Numerous castings of various designs made in the course of daily foundry practice have been rejected in this way, and these, on being annealed correctly, have in all cases been found to withstand the water pressure which previously they had failed to do.

Two particular instances are worth recording as showing the advantage of annealing material which, although apparently sound, has failed to comply with specified tests. They were both test bars cut from large castings, and whilst the first gave a tensile strength of 14·4 tons, the elongation was only 5 per cent. when normal. On annealing this at 700° for 30 mins. the tensile strength was raised to 18 tons and the elongation was increased to 25 per cent. In the second case both the tensile strength and elongation were low in the normal bar, being 11 tons and 8 per cent. respectively. This metal was improved by annealing to give the remarkable results of 15 tons tensile strength and 26 per cent. elongation

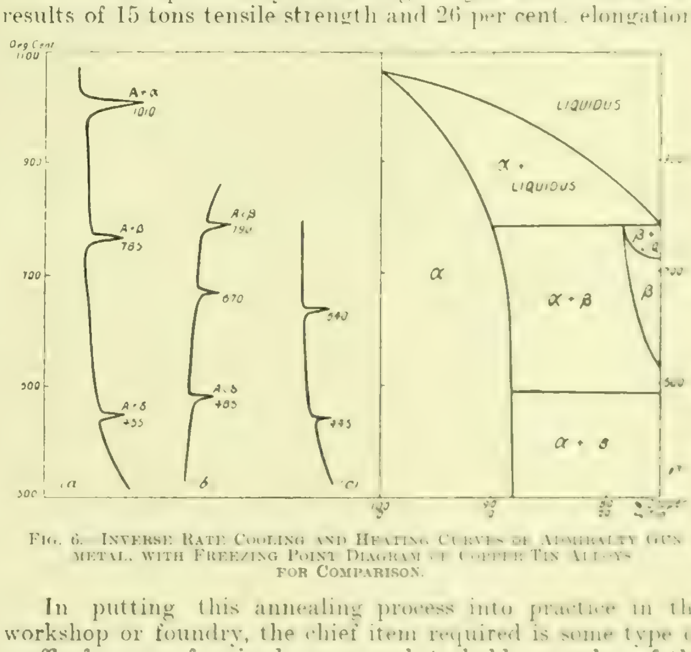


FIG. 6. INVERSE RATE COOLING AND HEATING CURVES OF ADMIRALTY GUN METAL, WITH FREEZING POINT DIAGRAM OF COPPER TIN ALLOYS FOR COMPARISON.

In putting this annealing process into practice in the workshop or foundry, the chief item required is some type of muffle furnace of a size large enough to hold a number of the castings to be treated. For maintaining a uniform temperature during the annealing, as also for regulating the rate of heating and cooling, it is necessary to employ either gas or oil firing. The temperature must be controlled by a pyrometer installation, and the workman in charge of the opera-

tion should be under supervision to ensure that he does not exceed either the temperature or time limits found to be needed for each class of casting under treatment.

Hardness. As it is sometimes of practical value to have an idea of the relative hardness of gun-metal under the various treatments accorded it, Table VI. has been prepared to show the changes in the values got by the Brinell method of determining this property. It is noteworthy that the hardening effect of chilling the metal is even greater than that of quenching, and that annealing does not completely remove this difference.

TABLE VI.—*Hardness of Heat-treated Gun Metal.*

	Bars.	Normal.	500°.	600°.	700°.	800°.
Brinell's Hardness Numbers	E.D.Q.	52	77	65	61	74
	F.D.A.	63	65	61	60	60
	G.C.A.	86	80	75	74	70

Corrosion.—As the result of recent researches with the brasses and bronzes it has been shown that one most serviceable method of getting over the trouble of corrosion is to eliminate the presence of all eutectic from the structure. This is accomplished by the addition of other metals in the production of proprietary "alloys"; whereas it would appear that gun-metal may be quite as immune from such trouble by the simple operation of annealing, whereby the eutectic is destroyed. Further tests are in progress with the object of determining how far this surmise is realised in actual corrosion tests, and the results of these may form the subject of a future paper to the Institute.

Summary—The heat treatment of Admiralty gun-metal has been investigated by quenching and annealing bars cast in dry-sand and chill moulds. The treated metal was tested physically and examined microscopically. (1) The tests show that no improvement may be expected by quenching, which lowers the strength of the material. (2) Simple annealing of the metal for 30 mins. very considerably increases its strength and elongation, the maximum results being obtained after annealing at 700° C. (3) The homogeneity and other physical properties of the metal are correspondingly improved, but particularly the capability of the castings to withstand hydraulic pressure. (4) These results are considered to be due to the removal of the eutectic from the microstructure, which after annealing shows only the crystals of α solid solution. (5) It is anticipated that this heat treatment will minimise corrosion difficulties.

The authors take this opportunity of expressing their warmest thanks to the firm of Messrs. G. & J. Weir, Ltd., of Cathcart, for kindly granting the use of their extensive foundry and equipment in carrying out this research, and also for so magnanimously granting permission for the publication of the results, which the authors hope will have far-reaching effects in the practice of gun-metal founding.

METAL QUOTATIONS.

TUESDAY, MARCH 18TH.

Aluminium ingot..	95/- per cwt.
„ wire, according to sizes, &c. ......from	112/- „
„ sheets „ „ ...... „	120/- „
Antimony.......................................£34/-/- to	£36/-/- per ton.
Brass, rolled	8½d. per lb.
„ tubes (brazed)	10⅛d. „
„ „ (solid drawn)..	9d. „
„ „ wire	8⅜d. „
Copper, Standard..	£64/7/6 per ton.
Iron, Cleveland..	64/10½ „
„ Scotch	70/10½ „
Lead, English	£16/7/6 „
„ Foreign (soft)	£15/18/9 „
Mica (in original cases), small	6d. to 3/- per lb.
„ „ „ medium...........................	3/6 to 6/- „
„ „ „ large	7/6 to 11/- „
Quicksilver..	£7/10/- per bottle.
Silver	26 3/16d. per oz.
Spelter	£24/10/- per ton.
Tin, block	£208/10/- „
Tin plates	13/10½ „
Zinc sheets (Silesian)	£28/-/- „
„ (Stettin; Vieille Montagne)...............	£28/2/6 „

INDUSTRIAL AND TRADE NOTES.

Labour Co-partnership.—In connection with the annual meeting of the Labour Co-partnership Association, the following figures have been circulated by the society: In 1883, when the association was formed, there were only 15 societies formed to carry out co-partnership principles, and their total capital amounted to £103,436, while their trade was £160,751 for the year. The profit realised during the year was £9,031. In the year under review the number of societies had increased to 110, the capital to £1,991,551, the turnover to £4,681,429, the profits to £228,189, and the dividend paid on wages was £29,847.

Launch of a Geared Turbine Steamer.—The new geared turbine steamer "King Orry," which was launched at Birkenhead on the 11th inst., for the Isle of Man Steam Packet Company, is to be completed about the end of May, and will be placed on service between the Isle of Man and Ardrossan about the third week of June. The King Orry is 312ft. in length, and will have a speed of 21 knots, with accommodation for about 1,600 passengers. The propelling machinery consists of two high pressure and two low pressure Parsons turbines, driving twin screws at 300 revs. per minute through double helical gearing of the Parsons type.

The World's Rubber Production and Consumption.—According to statistics recently published the total production of wild and plantation rubber throughout the world in the twelve months ended June 30th last, amounted to 93,669 tons, as compared with 79,302 tons in the previous year. The total consumption in 1911-12 was 99,564 tons, as compared with 74,082 tons in 1910-11, or an increase of 25,482 tons. The world's stocks of rubber on July 1st, 1912, are stated to have been 10,181 tons, as against 12,563 tons on the same date in 1911. The considerable expansion in consumption in 1911-12 is attributed largely to the lower level of prices prevailing during the year.

Employment in the Engineering Trades.—The "Board of Trade Labour Gazette" states that in February there was a decline in the iron and steel and tinplate industries. The percentage of "insured" workpeople unemployed fell from 5 at the end of January to 4·4 at the end of February. The upward movement in wages continued. Compared with a year ago, nearly all the principal industries showed an improvement. By the changes in rates of wages taking effect in February, 228,700 workpeople benefited to the extent of £9,700 per week. The estimated number of working days lost by disputes during the month amounted to 593,200, as compared with 651,200 in the previous month, and 463,500 in the corresponding month of last year.

Aerial Passenger Service from Dusseldorf to Ghent Exhibition.—At the present time, when the powers of the German Zeppelin airships are being so widely discussed, the news that a contract has just been signed by the Zeppelin firm and the directors of the Ghent International Exhibition for a regular passenger service from Dusseldorf to the Exhibition grounds is particularly interesting. The service will be maintained throughout the months of August, September, and October, and the fare for the flight, which is about 130 miles, will be £14. The regular arrival and departure of the great airships will give English visitors to the Exhibition a valuable opportunity of studying them at close quarters, and the low price of the passenger fare will undoubtedly induce a great number to make a flight.

Toll of the Railways.—The Railway Department of the Board of Trade issued on the 12th inst. a Blue Book containing a summary of accidents and casualties reported as having occurred upon the railways of the United Kingdom during the three months ended September 30th last. The total number of persons killed was 276, as compared with 290 in the corresponding period of 1911, whilst 2,329 persons received injuries as against 2,291. In addition to the above the following accidents occurred upon the companies' premises, but in which the movement of vehicles used exclusively upon railways was not concerned, namely, one passenger, 19 servants of companies or contractors, and 17 other persons killed, and 184 passengers, 5,497 servants, and 167 other persons injured, making a total in this class of 37 persons killed and 5,848 injured.

Nationalisation of Mines and Railways.—Replying to a deputation from the Parliamentary Committee of the Trade Union Congress, the Prime Minister, in the House of Commons a few days ago, said that, in view of the enormous variety of the conditions under which the mining industry is carried on in this country, and the complexity of the whole system, he should look with hesitation on any proposals to transfer the mines to the State as going concerns. The railways, however, stood on a different footing, and here there were practical difficulties in the way of a very serious kind. He predicted that the nationalisation of the railways would be immediately followed by large demands from the trading com-

munity for better terms in the matter of rates, and from the workers a demand for better conditions as to hours of labour. He kept an open mind on the subject, but the burden of proof rested on those in favour of the proposal, and this had not yet been adequately demonstrated.

Steam Engine Makers' Report.—The March report of the Steam Engine Makers' Society states that trade is still exceptionally good, and by all appearances likely to remain so for some time to come. There is a steady demand for men in most industrial, and especially shipbuilding, centres. The changes in rates of wages taking effect in January affected over half a million of workpeople, whose wages were increased by nearly £27,000 per week. Regarding the demarcation dispute between boilermakers and fitters in connection with the building of bolster wagons at Gateshead railway shops, the report says that the fitters went to the utmost lengths of conciliation to appease the appetite of their boilermaker friends, but they found it insatiable, as in reality their demands, notwithstanding that half the number of the wagons had been satisfactorily completed by fitters, amounted to the whole job being handed over, lock, stock, and barrel, from the erecting shop to the boiler shop. This they were unable to agree to, and the boilermakers had referred the matter to arbitration under the rules of the Engineering and Shipbuilding Federation.

Control of Winding Engines.—A demonstration of a new apparatus for controlling the speed of winding engines and preventing over winding was recently given at the Glasgow Iron and Steel Company's Parkneuk Colliery, Motherwell. In carrying out the tests the engine was allowed to run at its full speed, and without being touched by the engineman. When the cage was a considerable distance from the top of the pit shaft the apparatus came into operation. It shut off the steam, brought the reversing motion into its central position, and applied the brakes, with the result that the engine was brought to a dead stop in less than two revolutions. The test was carried out several times and always with the same result. The cage was then brought to the level of the pit mouth, and the steam was turned on to the engine without its being reversed. It will be understood that without the apparatus the cage would have gone right up to the rope pulleys and caused a serious accident, but instead of this happening the apparatus came into operation immediately, and the cage was stopped when it had only travelled 18in. The apparatus, which is patented, is being put on the market by Messrs. Shearer & Pettigrew, engineers and ironfounders, Wishaw.

Workmen's Compensation.—An interesting summary of the working of the Workmen's Compensation Act in 1911 is contained in the quarterly report of the Trade Union Congress Parliamentary Committee just issued. Figures are given relating to mines, quarries, railways, factories, harbours and docks, constructional works, and shipping. In these industries 139,884 employers sent in returns. During the 12 months under review, 4,021 persons lost their lives by accident, and 419,031 workers were temporarily disabled. The average amount paid in the fatal cases was £154, and in the temporary cases £5. 16s. As to the cost to various industries, mining is the most expensive, working out at 23s. 8d. per annum for each person employed, or 1·1d. per ton of coal raised. Docks come next, with 21s. 9d. per worker per year; followed by constructional works at 13s. 5d.; shipping at 14s. 3d.; quarries at 10s. 9d.; and railways at 7s. 11d. per person employed. The greatest immunity from accident is enjoyed by factory workers, as the cost is only 4s. 6d. per worker per annum. The average cost per person employed, taking all the industries together, is 8s. 5d. per year, or only about 2d. per week. While the cost is low, the amount paid in the aggregate is very large, as the total sum paid in all cases was £3,056,404, as compared with £2,700,325 in 1910. During the year there were 423,000 claims paid, of which only 5,767 had to be settled in the courts, 4,504 of the cases being decided in favour of the workmen.

Agricultural Machinery in Spain.—Prior to 1898 there was but one establishment in Spain for manufacturing agricultural machinery and implements, and the most primitive tools were (and still are) used by the average farmer. In that year the importation of foreign machines and implements began, which, in 1900, amounted to £45,000. Imports have increased year by year, and in 1911 amounted to £216,120, of which the United States furnished £70,340, and Great Britain, Germany, and France, in the order named, amounts ranging from £40,000 to £35,000; Canada furnished £7,000, and various other countries the balance. In the meantime the manufacture in Spain of agricultural machinery, particularly of ploughs, fanners, and thrashers began, and there are at present factories of considerable size at Barcelona, Saragossa, Araya, Valladolid, Vitoria, Lerida, and Valencia, besides many small factories. It is estimated that their combined production is more than double the quantity imported into Spain. According to the American Consul at Madrid, agricultural engineers have been appointed and schools established at various places. A commission has also been appointed by the Government to aid Spanish manufacturers in selecting types best adapted to the use of Spanish agriculturists. The slow progress made in extending the use of modern agricultural machinery and implements in Spain is attributed by the Government to the poor means of communication throughout the country which have prevented the farmer from seeing such machinery in actual use and kept him in ignorance of its practical value.

Methods of Packing Ferro-silicon.—A recent American Consular report contains a description of the methods of packing ferro-silicon, as adopted by the Swedish firm, the Gullspangs Eletrokemiska Aktiebolag. "For packing," they state, "we principally use iron-bound wooden cases in two sizes, one (for 50 per cent. ferro-silicon) containing about 287lbs., and one (for 75 per cent.) holding about 353lbs. The boxes have always been unlined and were made at first of unrabbeted ½in. stock, but since last year we have employed rabbeted stock, as the loss of contents in transit was found to be too great with unrabbeted boards. Water-tight packing being required for Germany, we pack goods for that country in second-hand paraffin barrels; these are, of course, both water and gas tight, but no fault has been found with them. On all our very latest shipments we have, at the request of foreign sellers, begun to pack ferro-silicon in sheet-metal cylinders containing about 375lbs. and have made four holes, 0·276in. diam., in the top to provide against excessive pressure in the cylinders. The regulations in force are different for different countries (e.g., for transport on some English railways each package must have three 1in. holes to permit the escape of any gases that may form). In our opinion, the dangers connected with the transportation of ferro-silicon can never be entirely avoided until uniform international regulations are adopted. In this connection it should be noted that danger is present only when the silicon content is between 35 per cent. and 65 per cent.; under and over these proportions ferro-silicon is much more stable. So far as we are informed, accidents have never happened except with about 50 per cent. If, as we hope, an international regulation regarding packing and transportation can be established, regard should be had to the last-named fact, and different regulations adopted for 25 per cent., 50 per cent., and 70 per cent. goods, or those of higher percentages."

CORRESPONDENCE.

The Efficiency of Cross Water Pipes in Lancashire Boilers.

To the Editor of "The Mechanical Engineer."

Sir,—There appears to be a considerable diversity of opinion with regard to the advantages or otherwise of fitting taper tubes (known as Galloway tubes and numbering anything from five to eight per furnace) in the flues of Lancashire and other cylindrical boilers. A canvass taken amongst steam users personally known to me elicited the following results:—

No. of works	36
No. of boilers	209
No. of boilers fitted with cross tubes	78
Approximate number of cross tubes	539
Difficulty of cleaning internally	all
Found advantage in steam raising	7
Not noticed any advantage	11
No experience with cross tubes	11

The remaining seven persons do not express any opinion for or against the use of these tubes. It is generally agreed that no appreciable danger is caused by defects which may develop in the tubes. On the other hand, the various insurance companies do not appear to favour them, though it might be suggested that they are not quite so much concerned with the economy of boilers as with the safety of the same. I should therefore be greatly obliged if some of your readers who are using, or have used, these tubes and are in a position to state as to whether any benefit as regards economy in fuel has been experienced (1) after fitting tubes to existing boilers; or (2) replacing plain tube boilers by those fitted with cross tubes, will give their experience. I should also like to know if the fitting of cross tubes (although it may possibly give a greater economy) causes a slightly less output of steam due to the decrease of draught allowing of only a smaller quantity of coal to be burnt per square foot of grate.—Yours faithfully,

JOHN P. CLAPHAM.

Emm Lane, Heaton,
Bradford, March 12th, 1913.

[Some observations on this letter will be found in our editorial columns.—EDITOR.]

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 58, New Bailey Street, Manchester.

MECHANICAL, 1911.

Manufacture of zinc from poor zinc ore and tailings. Beauchamp 17648.
Utilisation of peat. Rigby & Testrup. 26349.
Spraying valve mechanism for slow combustion engines. Tanner 28901.

1912.

Internal combustion engines. Still. 1750
Hydraulic transmission of power. Cleaver. 1982
Turbine installations. Parsons. 2130.
Water-gauge try-cocks. Reid. 2710.
Ignition in internal-combustion engines. Wilks. 3404.
Means for maintaining nuts and bolts in tightened position. Wills, and Low Moor Company. 4293.
Internal-combustion engines with compound cylinders. Sisson. 4313.
Valvular arrangements of ammonia-gas compressors for refrigerating machines. Early & Early. 4375.
Silencers for internal-combustion engines. Hutton. 4463
Fire bridges for furnaces. Trolley. 4514.
Manufacture of steel. Dixon. 4619 and 4620.
Carburetters for internal-combustion engines. Brown, Mills, and Clement Talbot, Ltd. 4695.
Wheel cutting machines. Llewellin. 4859.
Furnaces. Boult. 4908.
Process of and means for removing deposit from the cylinders and pistons of internal-combustion engines. Griffin. 4954.
Valve-mechanism for internal-combustion engines. Dubois. 5022.
Absorption dynamometer. Griffin. 5055.
Means for automatically regulating the supply of steam to suit the load. Barron. 5064.
Process of making steel. Reese & Wales. 5098.
Device applied to explosion motors for carburetting air with crude naphthalene. Lion. 5139.
Liquid weighing meter. Sleat. 5166.
Armoured ships. Dawson & Buckham. 5228.
Briquette presses. Crochet. 5229.
Setting of boilers. Poulton. 5231.
Mechanism for operating screw down-stop valves. Boyd. 5275.
Steam generators. Howden. 5383.
Process of soldering solid cable chains. Maisenbacher & Bürck. 5406.
Remelting and refining old or scrap copper alloy. Rockey and Eldridge. 5445.
Water-tube boilers. Yarrow. 5448.
Gas producers. Moore, and Dowson & Mason Gas Plant Company. 5500.
Automatic air brakes. Fyfe. 6048.
Variable-speed transmission gearing. Kimberley, and James Cycle Company. 6606.
Valves for slip pumps. Clarke. 6853.
Carburetters for internal-combustion engines. Longford, Clark, and Longford. 6863.
Speed governors. Fraser & Chalmers, Ltd., and Pochobradsky. 7282.
Change-speed gearing. Sedger. 7626.
Steam superheaters for tubular boilers. Hughes. 8288.
Carburetters for internal-combustion engines. Rotherham and Johnson. 8761.
Tractors. Martyn. 8856.
Erection of steel towers. Ginders. 8975.
Integrators or planimeters. Sturgeon. 9635.
Dirigible balloons. Short, Short, & Short. 9703.
Compressor pumps. Ruwell. 9917.
Device for taking up slack in wire rope and other flexible connections. Shield, and Vacuum Brake Company. 10064.
Exhaust lift valves for internal combustion engines. Jorgensen. 10217.
Pumps for exhausting and compressing or forcing air and other fluids. Drysdale & Displayer Company. 10845.
Fractional rope grip. Ottino. 10942.
Sluice or gate valves. Munro & Anderson. 11207.
Windmills for driving electric generators. Turnbull. 11240.
Devices for indicating and recording the speed and drift of ships. Dillberg & Petersson. 11265.
Aeroplanes. Bomhard. 12061.
Ejectors for vacuum brake apparatus. Gresham. 12595.
Boring and turning lathes. Watchorn. 12894.
Rotary valves for internal-combustion engines. Ménagé. 13135.
Lubrication of motors. Serex. 14016.
Water-tube steam generators. Cooper. 14632.
Reversible turbines. Mitchell & Sleator. 14883.
Treatment or renovation of foundry sand. Poulson. 14972.
Speed and revolution direction indicating and recording apparatus. Kenney, and American Speed Indicator Company. 15472.
Flying machines. Watkins & Beitzel. 16038.
Devices for indicating and recording the movement of ships. Dillberg & Petersson. 16529.
Driving chains. Coventry Chain Company, Hill, and Rowland 16604.
Automatic inlet valves. Stupecky. 17053.
Reversing valves for regenerative furnaces. Maerz. 17542.
Internal-combustion engines. Kieling. 18014.
Driving chains. Becker & Töns. 18427.
Speed-indicating apparatus. Beermann & Balzer. 18845
Bar-chucking mechanism for machine tools. H. W. Ward & Co., and Deakin. 18874.
Apparatus for compressing air or gas. Melmore. 19138
Liquid-fuel burners. Bryne. 19391.
Spanners and wrenches. Ashley. 19466.
Circular calculators. Fowler & Fowler. 20416.
Automatic coupling for railroad rolling stock. Leslie 20501
Piston packing rings. Leay. 20627.
Gas engines. Wade. 20824.
Boiler-flue cleaning apparatus. Liddle. 20891
Aeroplanes. Roukawischnikoff. 20941.
Means for delivering measured quantities of liquid. Pindstofte. 21629.
Apparatus for supplying measured quantities of liquid to carburetters. Dick. 21802.
Aeroplanes. Jackson. 23880.
Arch constructions for furnaces. Orth. 24167.
Carburetters for internal-combustion engines. Schatmayer. 24641.
Rolling of metal bars. Alexander. 25212.
Ball bearings. Hoffmann. 28217.
Gas producers. Tangyes, Ltd., and Robson. 28504.
Aerial machines. Whatton. 28558.
Apparatus for making cores of any cross section for metal casting. Kurze. 29377.
Exhaust silencer for internal-combustion engines. Tobey. 29553.
Toothed gearing. Von Bonfort. 29811.

1913.

Grinding machines. Kündig. 1164.

ELECTRICAL, 1912.

Electrically controlling steering gear on ships, swing bridges, hydraulic accummulators, cranes, &c. Martin, Jackson, Campbell, Campbell, & Campbell. 1901.
Telephone systems and apparatus therefor. Mellinger. 4179.
Electric conduits. Longbottom & Farrer. 4426.
Alternating-current dynamos. Akt.-Ges. Brown Boveri, et Cie 4460.
Means for leading electric or other power into revolving structures. Bacon & Shepherd. 5336.
Dynamos. Price. 5981.
Protective devices for electric distributing systems. British Thomson-Houston Company, and Wedmore. 8569.
Electric circuit interrupters. Bijur. 9426.
Working submarine cables. Gott. 10534.
Arc light electrodes. British Thomson-Houston Company. 15483
Electrical transformers. Siemens Schuckertwerke Ges. 15647.
Electric retort furnaces. Bally. 16041.
Prepayment meter for use in the distribution of electricity. Allgemeine Electricitats-Ges. 16134.
Electric striking gear. Campiche. 17779.
Refillable electric fuse. Daum. 21240.
Polyphase alternating electric current commutator motors Siemens Schuckertwerke Ges. 21471.
Means for suspending arc lamps. G. Schanzenbach & Co. Ges 22549.
Driving mechanism of magneto ignition machines having oscillating armatures. Robert Bosch. 23046.
Electric cut-outs. Voigt & Haeffner Akt.-Ges. 23514
Dynamos. Breeden & Moore. 25366.
Means for reducing the duration of sparks produced by magneto-electric generators. Mascow. 27094.
Means for the protection of electric accumulators from flooding by sea water. Wehrlin. 28520.

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WILLIAM H. FOWLER
Wh. Sc., M.Inst.C.E.

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Electro-Metallurgy.

ALTHOUGH electricity in its practical applications enters more and more into work with which engineers are associated, few outside certain trades realise its ubiquity, especially in metallurgical operations, and the extraordinary advances that have been and are being daily effected by its aid. Its advent as a serious competitor with fuel in the melting and purifying of steel was considered at first as a piece of presumption, and though its growth in this direction is restricted to some extent by the necessity for a cheap supply of power, its conveniences in other ways in the shape of temperature regulation and control are winning a field in which simple fuel alone, however cheap, cannot compete, and he would be a sanguine individual who would set bounds to this domain at the end of the next decade. Steel was first made commercially by Mr. F. A. Kjellin, of Sweden, by melting together its constituents to form crucible steel. It was produced in lots of one ton or more at a melt, and with cheap power available the cost was below that of crucible steel made in the ordinary way. Quite a variety of electrical steel-melting furnaces are now in operation, and though the steps that have since been made in the application of electricity to steel melting have been confined mainly to the Continent and the States, the progress made has been very considerable, as may be judged from the fact that in 1911 the tonnage output amounted to no less than 128,510 tons. Pig iron would seem to be quite too cheap and simple a product for electric melting to have much opportunity as a commercial competitor with coal, but the thing has been done, and though the furnaces are small and situated in California and Sweden, where fuel is expensive and water power very cheap, a good deal of money has been sunk in developing the enterprise, and the fact remains that pig iron of this kind is not a chimera but an accomplished fact. Although it is not probable that electric pig iron will be a serious

competitor against the blastfurnace product, still there are certain qualities, Swedish charcoal pig, for instance, which command a very high price on account of their purity, and in this grade of material electric melting may find a large opportunity. Though steel and iron loom most prominently in the engineer's horizon of manufactures, there are numerous other metals and alloys in which electricity plays an even more important part. Take aluminium, a metal more abundant in nature than iron, and yet so difficult to separate from its compounds by chemical means that its production by such methods costs 5s. a pound. The application of electricity to the separating and refining operations has changed all this and enables the manufacturer to sell it at a profit at a little over 10d. a pound. Carborundum and artificial graphite are materials which not many years ago were unknown, though large industries now centre round these materials at Niagara Falls. When first produced, carborundum was sold for polishing diamonds and its price was from 12s. to 15s. an ounce. Now it is made by the ton in electric furnaces of 2,000 h.p. capacity from common coke and silica sand and produced so cheaply that it competes successfully with such natural abrasives like emery, while the purity of artificial graphite surpasses that of the natural product, and in its applications for lubricating purposes is in many ways reducing the friction of the world's machinery. Until quite recently silicon as a metallic element was so rare that it could be seen only in chemical museums, where it stood as a curiosity. Now it is being produced by the ton for a mere nominal amount by electrical means and is finding useful outlets in connection with steel making, copper castings, and in reducing other metals from their oxides. Calcium carbide is another product which sprang into existence almost by accident while its inventor was making experiments with an electric furnace. In connection with acetylene gas, this compound now finds innumerable outlets for illuminating and heating purposes. Titanium carbide, though not as familiar as calcium carbide, is produced much in the same way, and it has been shown that when applied as the tip of an arc light it gives the most efficient arc light yet discovered, with a light efficiency running up to three candle-power per watt of electrical energy. In other words, it permits of about 50 per cent. of the maximum possible conversion of energy into light, or about double that which has ever previously been attained. In later years the alloys of iron with the rarer metals such as chromium, tungsten, uranium, and vanadium have been largely employed in the manufacture of steel to produce the special varieties that are finding such extended use in high-speed tool steel, and parts of motors intended to develop a large amount of power with small weight, as in aeroplanes, dirigibles, &c. While the use of these is now common, few realise that their application has been rendered commercially practicable by the electric furnace, which alone in many cases permits of their manufacture. These numerous products of electro chemistry and metallurgy constitute only a portion of the list. Metallic sodium and magnesium, the chlorates so largely used in the making of matches and gunpowder, refining of metals, the production of cheap ozone, nitric acid, and gases like oxygen and hydrogen, with their countless and growing applications, are other examples which occur to one's mind at the moment, and very little search would reveal as many others.

Contributions to Technical Societies.

SOME observations by Prof. A. K. Huntington in the course of his presidential address to the Institute of Metals raises a point which will often have presented itself to those who take note of the preponderating extent to which technical professors figure as authors of papers presented to engineering and similar societies, and of the comparatively small number of papers that are contributed by heads of manufacturing firms who, from their special experience, are best qualified to deal with problems on which information is desired and which are presented for discussion. He took as his text an analysis of the membership of the Institute of Metals, and pointed out that while it had fulfilled its function as a society for bringing together manufacturers, users, and scientific men interested in non-ferrous metals, since the relative proportions of these three sections was 37, 34, and 29 per cent. respectively, an examination of the papers read before the Institute told a very different story, manufacturers contributing only about 9 per cent., users 15 per cent., and professional members 75 per cent of the papers read. This disparity, however, is not difficult to understand if one considers briefly the position. Manufacturers labour not only under the difficulty of being unable to ascertain how their material behaves in service, but, if free from this handicap, have often other potent reasons for silence. Time and opportunity for preparing papers are not easily secured by the man occupied with business affairs, and even if they were he is naturally reluctant to publish information which he has only acquired possibly by dint of long toil and costly experiment, especially if, as is the case in many metallurgical operations, he can secure no protection by patent against the unfair use of the knowledge he has gained except that of secrecy. Under these circumstances his silence is natural, and it therefore often happens that those who could give the most instructive contribution to a discussion decline to do so. Users are less limited by considerations of this kind, while they are in a position to glean much interesting information as to the behaviour of materials or appliances, and not infrequently are prompted to reveal them by a desire to find a remedy for some trouble. On the other hand, the professional members of an institution possess very often special facilities and opportunities for conducting investigations. These, if we may venture to say so, are not always perhaps of a practical character, although we would not for that reason underestimate any scientific contribution to the store of general knowledge, apart from which, publicity to many professors is as the breath of their nostrils, and, "when found to be made a note of," is almost a maxim of their lives in matters great and small. In fact, a consideration of the reasons that underlie the proportionate percentages of contributions by the several sections referred to are pretty much the same in each case, namely, self-interest. The manufacturer as a rule contributes little because he has little inclination, the user more because he has more inclination and more to gain, and the professor as a rule talks a great deal because he likes to.

Imperial Motor Transport Conference.—The Imperial Motor Transport Conference will take place in London in July. According to present arrangements, it is anticipated that Prince Arthur of Connaught, the president, will receive the delegates on July 18th, and that on July 19th the delegates will visit the Industrial Motor Vehicle Exhibition organised by the Society of Motor Manufacturers and Traders, which will that day open at Olympia. The subjects to be discussed at the meetings of the conference include the question of fuel supply, the consideration of the problems of Imperial military motor transport with special reference to the production of types of vehicles useful both for military work and for industrial work in the Dominions and Colonies, the organisation of motor transport systems for the carriage of goods and their value to the mercantile life of the community, the relations between British manufacturers and buyers overseas, road transport in cities, and rural transport and the uses of the motor to the agriculturist.

THE CORROSION OF ALUMINIUM.*

BY G. H. BAILEY, D.SC., PH.D.

TAKEN in its widest sense, the question of the corrosion of aluminium is much too large to be dealt with in a single communication. Furthermore, it is of a diverse nature both in regard to methods of enquiry and to results, so that when we examine the action of the atmosphere or atmospheric agencies, the action of water under varying conditions and purity, the action of mineral or organic acids, of alkalies and alkaline salts, and of organic liquids, we are confronted with a series of sectional and more or less independent investigations. In the present communication I propose to confine myself to the consideration of the corrosion of aluminium by water and by solutions of common salt, and to give some of the results of investigations with which I have been from time to time engaged during the past three years. The literature connected with this subject is already quite considerable, and I do not intend to refer to it in detail. Many of the experiments that have been published are, however, open to criticism, partly on account of the methods employed and partly in consequence of the material upon which the experiments have been made, and hence the conclusions that have been drawn are apt to be misleading.

There are, for instance, investigations from authoritative sources in which the rate of corrosion is determined by reference to the weight of metal employed, when manifestly this factor must be referred to the surface exposed to action. In some cases the value attaching to estimates is lessened by the consideration that the samples of metal used were of a very low grade of purity—usually under 99 per cent. purity—whereas the bulk of the metal which is supplied for commercial use, in this country at all events, is of 99 per cent. to 99·5 per cent. purity. Moreover, impurities which are still liable to exist in the metal, such as sodium and copper, and which have a very marked effect on the extent of corrosion, are apt to be ignored in the investigation of corrosion, whilst other impurities whose effect is usually negligible are given too large a significance. An interesting series of determinations bearing upon the effect of copper on corrosion appears in the eighth report of the Alloys Research Committee, by Carpenter and Edwards, pages 216 and 254.

Estimation of the Extent of Corrosion.—The first step towards obtaining some definite knowledge relating to the corrosion of aluminium must involve the adoption of a method of ascertaining with approximate accuracy the amount of metal removed or acted upon during the exposure, and it is perhaps of greater importance that the method adopted should be capable of use in the hands of different experimenters and yield comparable results than that it should be rigidly accurate.

If aluminium sheet be exposed to the action of water for some days, it will be found that the water becomes slightly turbid owing to the formation of hydrate of alumina. On the sheet being removed and the surface rubbed, a further amount of such solid matter is obtained. It is seldom, however, that the whole of the adherent deposit can be removed by rubbing, for the sheet will, even after such treatment, usually be found to be slightly heavier than it was when first placed in the water. The deposit on its surface, though essentially alumina, varies in character and composition according to the nature of the aluminium sheet and of the water employed, and, with impure waters, may contain some matters derived from the water itself.

Messrs. Heyn and Bauer (Königliche Material prüfungsamt Gross Lichterfelde West) recognised the difficulty of removing and estimating such deposit, and determined the adherent portion (which is as a rule larger than the amount suspended in the water) by exposing the sheet subsequently to the action of dilute sulphuric acid, evidently on the assumption that the acid would dissolve the deposit without notably attacking the metallic aluminium.

Unfortunately, the reverse is the case, for usually the exposure necessary to remove the deposit is so prolonged that it is quite impossible to ignore the action of the acid upon the aluminium, nor have I found it practicable even by a consecutive series of immersions and weighings to arrive at the amount of the deposit in this way. The association of chromic acid with sulphuric acid hastens the removal of the deposit, but does not attain the desired result. Other reagents and other means have been tried, but without any satisfactory issue. I have therefore, in my experiments, used the method now described.

Method for Determining Rate of Corrosion.—A sheet of aluminium, of at least 100 sq. cm. surface, is cleaned by the application successively of ether, dilute caustic soda, and dilute nitric acid, subsequently being well washed and heated for some hours at about 100° C. to get rid of moisture. It is then weighed, the weight being taken as W. It is now totally immersed in, say, half a litre of water, or solution, at a known temperature, and left with occasional agitation for at least 48 hours.

The sheet is then removed and, so far as possible, cleared of deposit by rubbing. The whole of the substance so removed or previously suspended in the water is filtered off, ignited, and weighed. With good ordinary sheet this material consists almost entirely of alumina, and in view of minor corrections, which need not be referred to, may be taken as representing half its weight when expressed in the form of metal. The weight so found being represented as w, it is evident that, ignoring the adherent deposit, the sheet should now weigh $W - w$. Now expose the sheet for some hours to a temperature of about 200° C. to render alumina anhydrous, and weigh it. This new weight being represented as w', the expression $w' - (W - w)$ gives the amount of adherent deposit, and this similarly is reduced so as to be expressed in the form of metal.*

With very impure metal, or when very impure waters or solutions are employed, the residue obtained in both cases may be of more complex character, and must be submitted to further examination. But in general the amount of metal removed may be ascertained from the above factors. An actual example will make the matter clearer and indicate the order of magnitude of the materials dealt with. A strip of aluminium sheet, whose weight was 6·4978 grammes and surface 150 sq. cm., was exposed to good tap water at boiling temperature for eight days; the suspended deposit weighed 10 milligrammes; the sheet after rubbing weighed 6·5062 grammes. The deposits amounted to 10 and 13·4 milligrammes respectively, and the metal removed by the action of the water was thus 11·7 milligrammes. This represents a rate of corrosion amounting to very nearly 1 milligramme of aluminium per day per 100 sq. cm. of surface exposed.

Nature of Corrosion.—An examination of the liquid in which the metal has been placed shows that, except in waters containing free acid or alkali in notable quantity (and such waters are rare amongst domestic supplies), no aluminium whatever passes into solution, and that the corrosion is purely a question of oxidation of the aluminium to alumina at the expense of the oxygen dissolved in the water. This important result may be further established by exposing the metal to water from which the air has been expelled. Samples of aluminium sheet have indeed been exposed under such conditions, not only to water but also to a strong (15 per cent.) solution of common salt for several months without undergoing any corrosion. It follows also from this, of course, that, especially if the surface of aluminium be large in comparison with the volume of water used and no measures are taken for renewal of the air contained in the water, the rate of action gradually diminishes.

This is most strikingly the case when hot, and particularly boiling, solutions are used. For instance, a sample of sheet exposed to the action of water at about 95° C. for 30 days showed a rate of corrosion :—

During the first day		equal to	3·3	milligrammes	per 100 sq. cm.	per day.	
,,	next 7 days	equal to	1·2	milligrammes	per 100 sq. cm.	per day.	
,,	,, 11 ,,	,,	0·3	,,	,,	,,	
,,	,, 11 ,,	,,	0·1	,,	,,	,,	

This falling off is also partially due to the protective action of the deposit formed on the surface of the metal, so that vessels or tubing exposed to continuously heated water undergo very slow corrosion.

Limitations of the Method.—Determinations made by the method described above serve only to ascertain the amount

* Paper read before the Institute of Metals, March, 1913.

* The total aluminium removed [illegible] more simply expressed as [illegible] matter added to one half of [illegible]

of the metal removed by corrosion, and have little direct bearing on the specific nature of the physical phenomena or other exceptional conditions often associated with corrosion. Nor do they afford any explanation how it comes about that two particular samples, substantially of the same composition, may show somewhat different rates of corrosion; or to what extent the attack on the metal is evenly distributed over the surface, or more or less confined to pitting and small areas. Such problems, however, cannot be elucidated except by the application of special and independent methods of enquiry.

TABLE I.—*Index Figure and Composition of Samples.*

Index Figure.	Silicon per cent.	Iron per cent.	Aluminium per cent.	Remarks.
1	0·26	0·47	99·27	—
2	0·17	0·18	99·65	—
3	0·19	0·28	99·53	—
4	0·26	0·31	99·43	—
5	0·30	0·52	99·06	0·116 per cent. sodium.
6	0·30	0·49	99·12	0·09 per cent. sodium.
7	0·58	1·25	98·17	—
8	0·59	1·84	97·57	—
9	0·20	0·60	99·20	Unannealed.
10	0·23	0·20	99·57	Unannealed.
11	0·20	3·22	96·58	Unannealed.
12	0·64	0·37	98·99	—
13	0·37	0·23	99·40	—
14	0·23	0·18	99·59	—

TABLE II.—*Samples exposed to the Action of good Tap Water*

Index Figure.	Amount of Corrosion at		Remarks.
	10° C.	100° C.	
1	1·0	3·3	—
2	0·75	2·6	—
3	0·85	2·6	—
4	0·80	3·0	
12	0·85	2·5	In metal where the silicon exceeds the iron the corrosion products are almost entirely adherent to the metal.
13	0·75	2·6	
14	0·45	2·0	

TABLE III.—*Samples exposed to Solution of Common Salt.*

Index Figure.	Amount of Corrosion at Various Concentrations.						Remarks.
	At 10° C.				At 75° C.		
	1 per cent.	5 per cent.	10 per cent.	15 per cent.	3 per cent.	15 per cent.	
1	1·5	2·8	4·5	—	—	—	—
2	—	—	4·3	—	—	19·3	—
3	1·3	2·0	4·0	—	11·3	—	—
4	—	1·4	—	—	10·3	—	—
5	—	—	—	—	15·0	—	Contained much sodium.
6	—	—	—	—	18·6		Contained much sodium.
7	—	—	—	13·0	—	—	—
8	—	—	—	15·9		—	—
9	—	—		25·8	—	—	Unannealed.
10	—	—	—	24·0	—	—	Unannealed.
11	—	—	—	55·5	—	—	Unannealed.
12	—	8·5	—	—	—	—	—
13	—	6·5	—	—	—	—	—
14	—	6·0	—	—	—	—	—

The simpler question dealing alone with the extent to which good and well-annealed aluminium sheet is acted upon by various potable waters or solutions or reagents is one of supreme importance in regard to the commercial uses to which aluminium is put. I am also quite prepared to admit that in minor details the method proposed may be open to criticism, and that the values it gives are in all probability somewhat too high. A considerable experience of its application in practice, however, indicates that under the variations which occur normally in the course of investigation and also in the hands of different observers, comparable and reliable results are obtained.

Experimental Results.—Tables I., II., and III. give the amounts of corrosion of metal, having various grades of purity and character, during exposure to water and solutions of common salt. I have also added, although this contribution is not intended to deal with the action of acids and alkalies, a few instances illustrating by way of comparison the rate of corrosion by weak solutions of some acids and of caustic soda. Though in the earlier part of the paper I have expressed the results in milligrammes per day per 100 cm.^{2}, the data given below are stated in grains per day per square yard of surface.

They may be converted into the metric form by dividing by 1·29. It may be added that a corrosion amounting to 10 grains per day per square yard, *i.e.*, 10 units, as stated above, implies the removal of a film [illegible]th part of an inch in thickness of metal by continuous action extending over a whole year.

Samples Exposed to Very Bad Tap Water.—These waters contained exceptionally large quantities of mineral matter, including alkalies; they had a distinctly alkaline reaction.

Amount of Corrosion at Various Temperatures.

Index Figure.	Water A.		Water B.		Water C.	
	10° C.	75° C.	10° C.	75° C.	10° C.	75° C.
1	2·3	15·8	3·2	23·2	3·3	19·3

Comparative Statement of Rate of Corrosion by Acid and Alkali.

Index Figure.	Good Water.	Decinormal H_2SO_4.	Decinormal HCl.	Decinormal NaOH.
1	1·0	3·5	21·0	770
4	0·80	10·0	35·5	708
12	0·85	7·7	29·8	898
13	0·75	5·0	19·0	868
14	0·45	6·1	11·9	836

General Conclusions from Foregoing Results.—(1) That in general the greater its degree of purity, aluminium is less acted upon by water and salt solutions. (2) That in presence of copper or sodium the corrosion is notably accentuated. (3) That where the percentage of silicon is higher than that of the iron the action is less pronounced in the case of water and acids, and more pronounced in salt solution. (4) That water and common salt solution, from which air has been expelled, have no corrosive action. (5) That corrosion is accentuated (*a*) at high temperatures, (*b*) by the presence of impurities in the water, especially alkalies. (6) That unannealed metal is much more seriously corroded than annealed metal, owing no doubt to the unequal physical condition of the metal in the unannealed state. (7) That the results obtained by acting on aluminium with acids or alkalies afford no definite indication of its behaviour in presence of water or aqueous solutions. Had it been possible to establish any parallel, the investigation of the corrosion of aluminium would have been much simplified, since the difficulties presented by the formation of suspended or adherent deposit would be eliminated.

Tractor Smoke Nuisance.—A case of interest to traction engine proprietors was heard at Doncaster on the 18th inst., when a locomotive owner was charged with using a locomotive that did not consume as far as practicable its own smoke. For the defence it was stated the engine was constructed on the most modern principle for consuming its own smoke, and nothing more could be done. If the magistrates were going to convict then no traction engine could possibly get along the highway. Mr. William Wellbury, engineer with Messrs. J. & H. McLaren, of Leeds said the engine was made on the very best principle for consuming its own smoke. A fine of 10s. and costs was imposed.

SOME EFFECTS OF SUPERHEATING AND FEED-WATER HEATING ON LOCOMOTIVE WORKING.*

BY F. H. TREVITHICK AND P. J. COWAN.

(*Continued from page 315.*)

Coal Consumption. — Feed-water heating and superheating may be employed in various arrangements or combinations. For moderate feed-heating the pump exhaust and part of the main cylinder exhaust are used. The former raises the feed temperature by 25° to 30° Fah., the latter to about 210° Fah. or slightly more. High degrees may be attained by continuing the process with a smokebox heater in series. Temperatures of 280° to 290° Fah. may thus be reached, with even 360° Fah. for short supplies, feeding to a boiler working at a pressure of 180lbs. per square inch. The smokebox heater may be used alternatively for moderate superheating, when a superheat of about 90° Fah. may be secured. Thus feed-heating to 210° Fah. and moderate waste-gas superheating may be combined. Finally, with the smoke-tube type of superheater, moderate and high-degree feed-water heating may also be adopted.

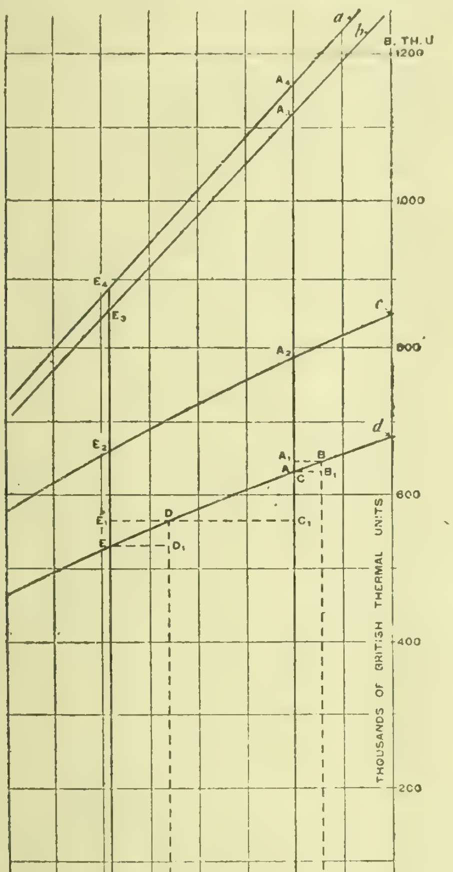


FIG. 10.—DIAGRAM SHOWING THE ECONOMY OF FEED HEATING TO 270° FAH.

From Fig. 2 it will be seen that for any reduction in the demand made on the boiler and denoted by a fall along the line *d*, the coal consumption falls along the line *a*. To this rapid fall are due the large economies effected with comparatively small thermal savings. The correspondence shown in Mr. Fry's paper between tests on boilers of a fair range of proportion, and in Dr. Goss's reports on boiler efficiency as affected by pressure, makes it permissible to take Fig. 2 to represent typical conditions in a brick-arch boiler working at 180lbs. pressure per square inch, generating practically dry steam.

(1) **High Degree Feed-water Heating.**—Installations giving average feed temperatures between 270° and 290° Fah. are described in Appendix I., under Types A and B. Unless conditions are unfavourable, feed-heating is purely a gain to the boiler. If an engine be overrated, hot feed may be accompanied by the production of somewhat drier steam. The effect of feed-heating may be studied by the aid of Fig. 10, which is part of Fig. 2 to an enlarged scale.

Taking as typical a rate of firing of 80lbs. per square foot of grate area per hour, by the scale, AX, the amount of heat utilised in steam production is 632,000 B.Th.U. This is equivalent to the evaporation of 591lbs. of water from and at 160·5° Fah., the temperature of discharge of the injector with supply at 65° Fah. and boiler pressure at 180lbs. Dividing this in the proportion of 11·2 : 1, gives 542,57lbs. as the steam taken by the engine, and 48·44lbs. as that used in working the injector. For a pump-fed engine (with supply at 65° Fah.) to develop the same power, the same number of pounds of steam must be furnished to the cylinder. This requires 542·57 (1197·7 – 33·07) = 631,890 B.Th.U., 1197·7 representing the total heat in steam at 180lbs. pressure, and 33·07 that in the water at 65° Fah., both above 32° Fah.* The pump consumption will be taken as 2·2lbs. of steam per 100lbs. of water delivered, and therefore (542·57 × ·022) lbs. = 11·94lbs. of steam are needed for the pump, equivalent to a demand on the boiler of 13,910 B.Th.U. The total number of thermal units to be generated is thus (631,890 + 13,910) = 645,800 B.Th.U. This, in the installations Types A and B (Appendix I.), is supplied in stages, namely, by the pump exhaust heating by 25° Fah., or to 90° Fah.; by the main cylinder exhaust to 210° Fah.; by the waste-gas heater to, say, 270° Fah. (a temperature easily reached); and finally by the boiler. The total heat supplied per 1lb. of steam is (1197·7 – 33·07) = 1164·63 B.Th.U. Of this, therefore, the pump exhaust furnishes (58·0 – 33·07) = 24·93 B.Th.U.; the main exhaust (177·99 – 58·0) = 119·99 B.Th.U.; the waste gases supply (238·8 – 177·99) = 60·81 B.Th.U.; and the boiler furnishes (1197·7 – 238·8) = 958·9 B.Th.U. The total heat is supplied to the engine and pump as follows:—

TABLE I.—*Heat supplied when Feed-heating to 270° Fah.*

Source of heat.	Proportion of Total supplied.	B.Th.U. supplied. To engine.	To pump.	To engine and pump.
Pump exhaust-heater	$\frac{24 \cdot 93}{1164 \cdot 63}$	13,530	300	13,830
Main cylinder exhaust heaters....	$\frac{119 \cdot 99}{1164 \cdot 63}$	65,100	1,430	66,530
Waste-gas heater ..	$\frac{60 \cdot 81}{1164 \cdot 63}$	32,990	730	33,720
Boiler	$\frac{958 \cdot 9}{1164 \cdot 63}$	520,270	11,450	531,720
	Totals ..	631,890	13,190	645,800

Instead of 632,000 B.Th.U. to be supplied by the boiler in the injector-fed engine, coal has now only to be burnt to furnish the reduced supply of 531,720 B.Th.U. Following this out in Fig. 10, the requirements have first to be increased from A to A_1 (= 645,800 B.Th.U.), on account of the substitution of the pump for the injector. This corresponds to a point B on the curve *d*. The use of the pump-exhaust reduces the demand by 13,830 B.Th.U., namely to B_1 and C, or slightly below the original point for the injector-fed engine. The main exhaust furnishes a further 66,530 B.Th.U., and the demand is brought down to C_1 and D, and again of this 35,720 B.Th.U. (DD_1) is derived from the waste gases, leaving EY (= 531,720 B.Th.U.) to be provided by the boiler itself. The rate of firing which will produce this is 60·8lbs. per square foot of grate area per hour, compared with the original 80; a saving of 24 per cent. is thus indicated for the system.

The diagram shows how this comes about, supposing smokebox conditions to remain normal. The heat represented by DD_1 is drawn from the waste gases. This length may, therefore, be set up over E at EE_1. Then E_1E_2 represents the final loss in the waste gases compared with the original AA_2, that is, 96,000 B.Th.U. instead of 156,000, or a reduction of 38·5 per cent. in this loss. The loss by unburnt fuel has been reduced from A_2A_3 (332,000 B.Th.U.) to E_2E_3 (193,000 B.Th.U.), a reduction of more than 41·5 per cent. The pro-

* Paper read before the Institution of Mechanical Engineers, March 14th, 1913

* The figures for heat in steam and water are taken from "Tables and Diagrams of the Thermal Properties of Saturated and Superheated Steam," by L. S. Marks and H. N. Davis. (Longmans.)

portion of the heat utilised to the total available has been greatly increased.

Estimating economy in this manner for various feed temperatures, a series of values are obtainable, and the Curve 1, Fig. 11, may be thus derived; Curve No. 2, Fig. 11, shows the corresponding thermal savings. The actual savings are greater than the latter would indicate, from indirect causes, which thermal calculations cannot take into account. The savings by feed-heating are, in locomotive work, on a rather higher scale than in other branches of steam engineering.

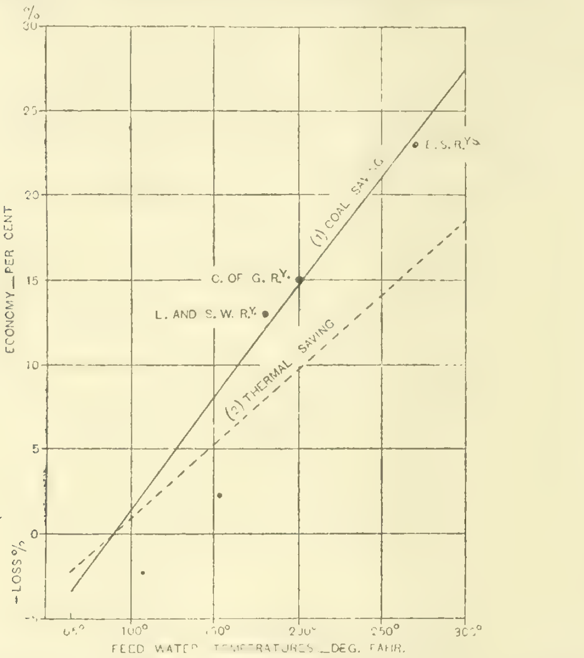


FIG. 11.—COAL SAVING (CURVE 1) AND THERMAL SAVING (CURVE 2) OF FEED-HEATING TO VARIOUS TEMPERATURES, WITH PUMP SUPPLY, COMPARED WITH INJECTION FEED.

Among many trials of this system on the Egyptian State Railways those made with Engine No 711 (Type A, Appendix I.), in the early part of 1908, are the most important. This is a 4—4—0 type engine. Engine No. 711, with heaters, ran against a sister engine, No. 695, without heaters, on expresses between Cairo and Alexandria (130 miles), the fastest timing being 3 hours with two intermediate stops. The coal was weighed into bags, sealed, and opened on the tender as required. The figures relate to coal used for train working only. The ton-miles accomplished were 1,939,847 by Engine No. 711 and 1,926,054 by Engine No. 695. The average coal per ton-mile worked out at 0·1116lb. for No. 711, and 0·1450lb. for No. 695—a saving of 23 per cent. for the heater engine. The results of the trials are depicted in Figs. 12 and 13. The consumption of the non-heater engine increased much more rapidly with the loading than did that of the heater engine. The economy shown by the latter improves at the heavier loads. Table II., giving the trains classified according to load (tare behind tender), shows this very clearly, especially on the pound per mile basis.

TABLE II.—*Trials of Feed-heater Engine No. 711 and Non-heater Engine No. 695.*

Class of Trains.	Engine No.	Actual Train Loads.	Coal consumption. Average lbs. coal per mile.	Saving in favour of Eng. 711	Average lb. of coal per ton-mile.	Saving in favour of Eng. 711
Tons behind tender.				Per cent.		Per cent.
Under 250	711	203·2	24·0	23·3	0·1185	21·8
	695	206·8	31·3		0·1516	
250–300......	711	268·3	30·2	20·9	0·1125	21·8
	695	267·6	38·2		0·1425	
300–350......	711	326·5	34·1	28·2	0·1046	28·6
	695	324·5	47·5		0·1465	
350–400......	711	362·4	38·2	31·3	0·1054	28·8
	695	375·8	55·6		0·1481	

The figures of the registers, for engines in regular service, confirm all trials made with this system. Table III. gives such records for Engines Nos. 711 and 677 and non-heater engines. The large difference between No. 711 and sister non-heater engines is probably in part due to No. 711 being constantly used for investigation work, and being kept in first-class order. Coal was also most likely booked to it more carefully than it would otherwise have been. The figures for No. 711 with and without heaters are fairly comparable. Engine No. 677 is of another class, being of the 4—4—2 type, with cylinders 18in. by 26in., heating surface of 1,535·5 sq. ft. in the tubes, and 140·25 sq. ft. in the firebox, and a grate area of 24 sq. ft. An all-round improvement in this case of 18 per cent. is shown for the heaters; but if the comparison be confined to periods of like climatic conditions (an important point when work in a country such as Egypt is being considered) this engine, fitted with heaters, showed an improvement of 20·5 per cent. over her working without them.

TABLE III.—*Service Working of Feed-heater and Non-heater Engines.*

	Engine No. 711 without heaters.	Engine No. 711 with heaters.	29 Sister engines without heaters.	Engine No. 677 with heaters.	Engine No. 677 without heaters.
Average load, tare behind tender	249·6	281·6	231	280	278·4
Average lbs. of coal per mile	41	35·9	40·2	37	45·1
Average lb. of coal per ton-mile	0·1643	0·1276	0·1749	0·1322	0·1622
Difference in favour of heaters on coal per ton-mile, lb.	0·367lb.	0·0473lb.		0·031lb.	
Ditto, per cent.	22	27		18	

Considering the modified smokebox arrangement, the result shown for the trials of Engine No. 711 (an economy of 23 per cent.) is in remarkably good agreement with the saving indicated by the method of Fig. 10. A point, indicating these trial results on the Egyptian State Railways, is marked on Fig. 11. Feed-heating has been carried to certain lengths on other systems, but not to such high temperatures as these. In England, on the Continent, and in America, feed-heating has been tried on a more or less extensive scale, but in most cases exhaust-steam heating only has been used. A point indicating results of the late Mr. Dugald Drummond's system, on the London and South-western Railway, has been inserted in Fig. 11, as well as one for a system in use on the Central of Georgia Railway (U.S.A.). All these points are in fair agreement with the curve No. 1 of diagram, Fig. 11. If part of the exhaust steam be efficiently employed in raising the feed to temperatures approaching the maximum, its utilisation in this manner is productive of more economical working than its use in the blast would be, in maintaining a higher smokebox vacuum.

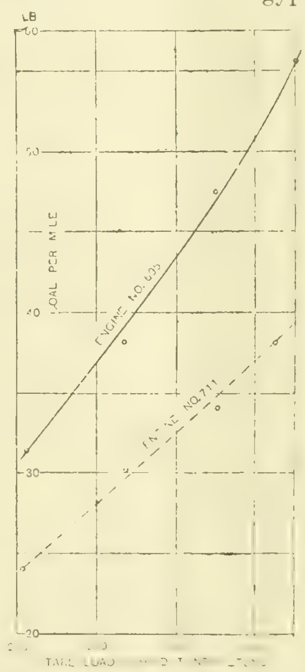


FIG. 12.—COAL CONSUMPTION PER MILE FOR ENGINE NO. 711 (FEED HEATING TO 270 FAH.) AND NO 695 (NON HEATER).

(2) **Moderate Degree Feed-heating and Moderate Superheating by Waste Gases.**— A typical installation of this class is described in Appendix I. (Type B). With supply at 65° Fah. the pump exhaust warms the feed to 90° Fah., and part of the main cylinder exhaust subsequently carries it to about 210° Fah. The waste-gas heater gives superheat of about 90° Fah. on a boiler pressure of 180lbs. per square inch. For the sake of moderation 85° Fah. will be taken.

According to Fig. 9, this degree of superheat reduces the steam consumption by about 9 per cent. Instead of the 542·57lbs. necessary in Case I., only 493·74lbs., therefore, need to be supplied to this engine for the same work. Each

1lb. contains, however, 1215·33 B.Th.U. above 65° Fah., and the total heat to be supplied for engine purposes is now $(493·74 \times 1215·33) = 600,060$ B.Th.U. The pump requires $(493·74 \times 0·022) = 10·86$lbs. of steam, which, taken from the dome, is saturated. This represents $(10·86 \times 1164·63)$ 12,650 B.Th.U., and the total engine and pump requirements amount to 612,710 B.Th.U., supplied as in Table IV.

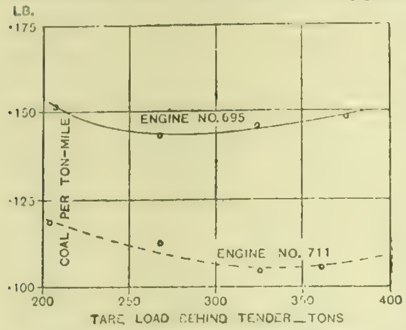


FIG. 13.—COAL CONSUMPTION PER TON-MILE FOR ENGINE NO. 711 (FEED HEATING TO 270° FAH.) AND NO. 695 (NON-HEATER).

In this case coal has only to be burnt to supply the 514,560 B.Th.U. demanded of the boiler (*see* Fig 14). As before, the demand is first increased from A to A_1 by the adoption of the pump. From the corresponding point B on the curve *d*, superheating reduces the total demand to B_1 and C (612, 170 B.Th.U.) Thence to C_1 and D (600, 130 B.Th.U.) the demand is lowered by the use of the pump-exhaust, and to D_1 and E (539,590 B.Th.U.) by the main exhaust-heaters. The superheater completes the process by relieving the boiler of duty equal to 25,030 B.Th.U., and the demand is brought down in this way to E_1 and F (514,560 B.Th.U.), corresponding to a coal rate of 58·1lbs. per square foot of grate per hour, compared with the original 80lbs., or a saving of nearly 27·4 per cent. EE_1 and FF_1 represent heat taken from the waste gases in superheating, and the loss in these gases is reduced from AA_2 (156,000 B.Th.U.) to F_1F_2 (102,500 B.Th.U.)—a saving of 34·3 per cent. The loss by unburnt fuel is restricted to F_2F_3 (173,000 B.Th.U.) in lieu of A_2A_3 (332,000 B.Th.U.)—a fall of 48 per cent.

TABLE IV.—*Heat supplied when using moderate Feed-heating and moderate Superheating.*

Source of heat.	Proportion of total.		B.Th.U. supplied. To engine.	To pump.	To engine and pump.
Pump exhaust-heater	$\frac{24·93}{1215·33}$	$\frac{24·93}{1164·63}$	12,310	270	12,580
Main exhaust-heaters	$\frac{119·99}{1215·33}$	$\frac{119·99}{1164·63}$	59,240	1,300	60,540
Boiler	$\frac{1019·71}{1215·33}$	$\frac{1019·71}{1164·63}$	503,480	11,080	514,560
Superheater	$\frac{50·7}{1215·33}$		25,030		25,030
Totals			600,060	12,650	612,710

Among others, two long series of trials of this class of installation have been conducted on the Egyptian State Railways. The most important was carried out in 1911, though the system had then been in actual operation for some time on a comparatively large scale. The heaviest scheduled trains between Cairo and Alexandria, having average speeds, deducting for stops, of between 42·4 and 43·3 miles per hour, with loads usually above 330 and frequently over 400 tons tare behind the tender, were worked. The heater Engine No. 706, five sister engines without heaters, and one engine of the same class (No. 712 as then fitted) with a high degree superheater and piston valves, were all run in one link working with three De Glehn compounds. The latter engines now usually handle these trains. They have cylinders 13¼in. and 22in. by 25¼in., total heating surface of 2,365·5 sq. ft., working pressure of 228lbs. per square inch, and total weight, with tender, of 107·25 tons. The engines of the 706 class weigh some 20 tons less than this. Their chief particulars are given in Appendix I. Coal was dealt with as previously described, but the records were kept for over-all service working, and not as in the trials there alluded to, for running time only. The figures in Table V., therefore, include lighting up, and some unavoidable light mileage, the latter, however, being negligible. In all these trials the checking of the coal was officially carried out by the Stores Department and by representatives of the General Manager. The provision of the coal in sealed sacks effectually prevented the favouring of any engine with selected coal. On these railways the Stores Department is always responsible for the coal until it is actually on the tenders. The figures of Table V. are from the report by Mr H. W. Davis (Member) to the general manager on these trials.

TABLE V.—*Trials of moderate Feed-heating combined with moderate Superheating.*

Engine Nos.	697, 713, 717, 720, 721.	706.	669, 674, 675.
System.	Ordinary.	Heater.	De Glehn
Average load tare behind tender ..	328·6	336	333·5
Coal consumption, average lbs. per mile	47·7	33·8	42
Economy in favour of engine No. 706 ..	29·2%	19·5%	
Coal consumption, av. lb. per ton-mile	0·1453	0·1005	0·1261
Economy in favour of Engine No. 706	30·8%	20·25%	

Engine No. 706 proved the most economical of the whole link, and showed 30·8 per cent. economy over the non-heater engines, and handled throughout the heaviest trains. It showed an economy of 20 per cent. on the De Glehn compounds.

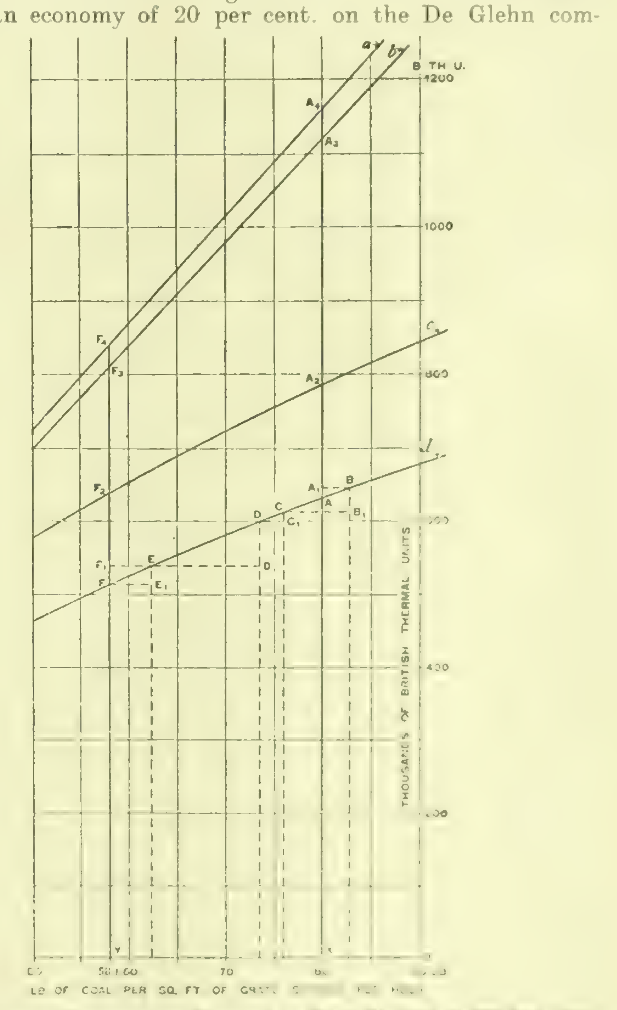


FIG. 14.—DIAGRAM SHOWING THE ECONOMY OF FEED HEATING [illegible] FAH. COMBINED WITH SUPERHEATING BY WASTE GASES [illegible] FAH.

The difference between the 30 per cent. economy shown in these trials and the 27·4 per cent. deduced by means of Fig. 14 may be due to several causes. The average superheat may be nearer 90° Fah. than the 85° Fah. taken above, or the saving indicated by the Purdue tests may not quite coincide with the actual saving, or again the difference may be due to excessive moisture in the steam produced in the ordinary engine.

(*To be continued.*)

LIQUID FUEL FOR SHIP PROPULSION.

AT a recent meeting of the Institute of Marine Engineers the discussion took place on Mr. C. Zulver's paper on "Liquid Fuel as a Source of Energy for the Propulsion of Ships," reproduced in our issues of March 7th and 14th last. The discussion was opened by Mr. H. Ruck-Keene, who said that although with reasonable care high-flash-point oil could be carried with the same safety as coal, precautions were necessary to prevent the oil coming in contact with materials which would readily ignite if saturated, and very much greater precautions were required with low-flash-point oils. For small powers the advantages of the 4-cycle engine in economy of fuel were apparent, but against this in the larger powers must be reckoned the extra weight, length, and number of cylinders required.

Mr. F. M. Timpson said he noted solar oil was the principal fuel used in the "Vulcanus." He asked if this was necessitated because of any difficulty in burning residual oils. There was, he said, no real basis for comparison, in actual sea-going experience, to show the superiority of the 4-cycle engine over the 2-cycle. He considered that difficulties would exist in using the heavier oils on slow-speed vessels. He stated that, in vessels up to about 200 h.p., principally for coasting purposes, the 2-cycle engine had been almost exclusively adopted, and was found to be most economical.

Mr. A. H. Mather commented on the prevailing high prices of fuel oils as a possible hindrance to the development of the internal-combustion engine, and said it was reassuring to have the author's statement that the demand would be met in the near future by increased facilities for distribution, &c. He also referred to a recent case of a fishing vessel where a gas was given off from the oil for a paraffin engine through contact with hot steam, resulting in an explosion on ignition.

Mr. B. P. Fielden asked how, in the absence of a steam coil, the residual oil in the "Vulcanus" was kept sufficiently liquid to be pumped.

Mr. B. H. Joy referred to the value of the paper as being the only record in print of the performances of large internal-combustion engines in marine work. He noticed that on the "Vulcanus" no governor was used, whereas one was fitted on the "Juno," and he asked if this made any difference in practice. He commented on the excellent facilities in the improved Werkspoor design for examination of the piston, and on various other matters referred to in the paper. He said opinion was divided amongst builders as to the use of relief valves. He confirmed the author's statements as to the ease with which the engines of the "Vulcanus" were handled. He believed in the use of a governor for Diesel engines.

Mr. R. Balfour emphasized the slight nature of the breakdowns on the "Vulcanus," as described by the author. He referred to a possible danger if cooling water containing sediment were used, causing choking, and possibly raising the explosive temperature.

Mr. Summers Hunter, jun., said it was apparent to anyone who had been in touch with actual sea-going conditions that the 4-cycle Diesel engine was much superior to the 2-cycle engine with regard to reliability, which was a point of primary importance. The unchallenged theoretical values of the 2-cycle engine could not be realised under present conditions, due principally to the difficulty of getting the pistons and cylinder heads of material strong enough to withstand the high temperatures.

Mr. W. E. Farenden pointed out that the author's estimate of a saving in weight was in regard to the 4-cycle engine, and as he had cited one case where the weight of a 2-cycle engine was almost double that of the 4-cycle, it was questionable whether there was any saving in this respect with the 2-cycle engine. He referred to the tendency of the price of oil to rise, and the uncertainty in this respect, he considered, would retard the development of the internal-combustion engine.

Mr. J. Shanks pointed out that in the comparisons between the m.v. "Vulcanus" and the s.s. "Sabine Rickmers," the author had deduced that 1 ton of oil was equivalent to 5 tons of coal; but if a more representative type of steamer had been selected, the ratio would only have been $3\frac{1}{2}:1$. On modern steamers, with forced draught and superheaters, the coal consumption had been brought down to 1·31lbs. per indicated horse-power per hour. The author had given the consumption on the m.v. "Juno" as ·49lb., and at the 5 to 1 ratio this would be equivalent to allowing 2·45lbs. of coal.

In connection with the comparative figures of the "Vulcanus" and "Sabine Rickmers," Mr. J. T. Milton drew attention to the fact that the "Vulcanus" was not representative of the best class of internal-combustion engined vessel, as her lines were exceedingly full and her propulsive efficiency was therefore below the average.

In the course of his reply, Mr. Zulver said that heavy residual oil which had not been subjected to any process of distillation was being used on the m.v. "Juno." It had not been found necessary to use any steam heating arrangement on the m.v. "Vulcanus" to liquefy the fuel. The engines on the "Vulcanus" had not been fitted with a governor, but they had proved to be remarkably free from racing, a result mainly attributed to the flywheel which had been fitted. It was difficult to estimate the saving in weight effected by the use of the Diesel engine; but this had been found to be from 12 to 17 per cent. If the exhaust gases did not exceed 380° Celsius in temperature, it could be assumed that the cylinders were not overheated. The trouble with the inblast air vessels had been overcome by the use of weldless vessels, which were suspended so as to draw off any possible accumulation of water. The "Sabine Rickmers" was fairly representative of ordinary marine work, as forced draught and superheaters were seldom used in that class of vessel. With regard to the use of the 2-cycle engine for smaller powers, he did not consider this to be an evidence of their superiority. This class of engine had been specialised for small vessels, while the 4-cycle engine had been adopted for the larger ships. Each case should be considered on its own merits and in relation to the different conditions of working. After much investigation it had been found to be best to use air to atomise the fuel. An important consideration with the Diesel engine was that on long sea voyages the engines had run continuously without any deposit being formed on the pistons and cylinder heads, and difficulty might be experienced in this respect with the direct injection.

The meeting closed with votes of thanks to Mr. Zulver and to the Chairman.

VICKERS' EXPERIMENTAL TANK FOR SHIP MODEL TESTING.

MESSRS. VICKERS, Ltd., Barrow-in-Furness, have laid down a new experimental model-testing tank at St. Albans. In the new tank particular attention is given to the lighting of the premises, both as to daylight and lighting by electricity. The workshops and offices are amply equipped, and there is a special model-shaping machine, based generally on the device of the late Dr. Froude, which was improved by his son, Mr. R. E. Froude, and others—especially as regards electric motors for driving. There is also an overhead travelling crane, worked by hand through an endless chain, for carrying the models—usually from 15ft. to 20ft. in length—from the casting chests to the shaping machine, and from the latter to the inner end of the tank, where there is the "trimming" recess, about 25ft. in length. The model carriage, as in the case of the corresponding apparatus in other tanks, is in general principle based on the apparatus designed by Dr. Wm. Froude. It was constructed by Messrs. Kelso & Co., Glasgow, and consists of a sparred structure formed of timber; its members being mostly of box section so as to obtain the maximum lightness with strength. It is 30ft. in length by 21ft. 6in. span, and it carries all the electric and magnetic apparatus for recording the diagrams taken in the course of the experiments. The truck runs on four main wheels, one at each corner, each with an electric brake, and with two smaller wheels supporting the truck about mid-length. It is driven by two 12 h.p. electric motors, the current for which is supplied from a charging dynamo and battery of storage cells. The tank, although in extreme length not quite equal to the National Tank at Bushey Park, has a clear length for experimental purposes of about 380ft. irrespective of the trimming extension at the inner end. The depth, however, is greater, being 13ft. instead of 12ft. 3in., and there is a clear width of 20ft. 10in. The truck rails are 21ft. 6in. apart.

THE COMMERCIAL ASPECT OF ELECTRIC COOKING AND HEATING.*

BY T. P. WILMSHURST.

The object of the present paper is to consider how far the use of electricity in the home is likely in the near future to supersede existing methods of cooking and heating. The question of lighting may be considered settled. The author's experience for some years past has been that all new houses within reach of the mains, of a rental value as low as 7s. per week, are now wired as a matter of course for electric light, even though the initial cost may be £4. 10s. per house as against 30s. or 40s. for gas, as the owners now realise that houses fitted with electric light have a better letting value. While the almost universal adoption of the metal filament lamp has resulted in the spread of electric lighting, it is unfortunate that the revenue per house has, due to the same cause, simultaneously dropped to one-half or less, while the cost of the service and meter remains the same. In view of future heating developments it is not advisable to reduce the size of service cable to such houses below, say, 7/18 S.W.G., and in any case the cost of, say, 20ft. of 7/18 cables is only about 1s. more than for a 7/20 cable. The obvious remedy is to seek other sources of revenue from the same consumer, and the most attractive problems at once appear to be cooking and heating.

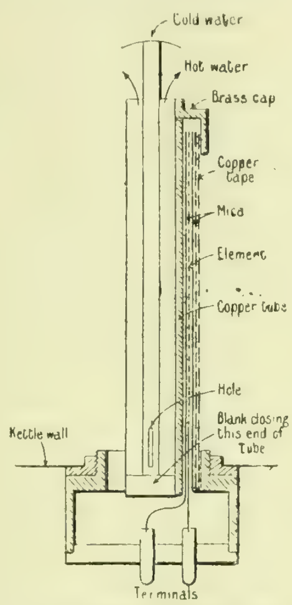


FIG. 1. SECTION OF 1,200 WATT "BERRY" CARTRIDGE ELEMENT.

Cooking.—It is no exaggeration to say that considerably more than half the revenue of a modern gas undertaking is derived from the cooking load. In a gas oven the joint of meat during the whole cooking operation reposes in an atmosphere consisting of the objectionable products of combustion of coal gas; and many consumers have, on taking up electric cooking, at once been struck with the vastly improved flavour of the meat. If it can be proved to the consumer's satisfaction that electric cooking is not more expensive than gas or coal-fire cooking, the battle will be won, as the innate advantages of the former are so considerable that progress is bound to be very rapid. Until recently electric cooking has been to all intents and purposes non-existent. The author's first experience, about three years ago, was with a "lagged" or "black" oven, which proved unsatisfactory. It is, in the author's view, largely due to the business foresight of one man, Mr. A. F. Berry, that substantial progress is now being made.

The advantages of electric cooking are: (1) Absolute cleanliness. (2) Absolute certainty of results, owing to the voltage limit restrictions laid down by the Board of Trade. This is in marked contrast with the result obtained with gas cookers, owing to the wide fluctuations of gas pressure in practice, or with the results with coal ovens. With the "Tricity" system absolute evenness of temperature is attained by a simple arrangement of deflectors fixed under the top heater and over the bottom heater. With an electric cooker it is only necessary to weigh the joint and allow 15 to 20 minutes per pound, according to taste, and at the predetermined time the joint is taken out with the certainty that the meat will be cooked perfectly, and without the door of the oven having once been opened. (3) A saving owing to the diminished loss of weight as compared with other methods.

A pork butcher in Derby cooks an average of 30 legs of pork per week, as well as pork pies, hocks, &c. For nearly six months this cooking has been done entirely on a "Tricity" double oven measuring 19in. by 28in. by 16in. internally. This consumer assures me that the saving of meat is so great so far to outweigh the cost of current at 1d. per unit. And whereas the loss on his coal range was formerly 30 per cent., this is now reduced to an average of 20 to 25 per cent. This consumer assures me that there is no comparison as regards the regularity of the results and the improved taste of the meat. If the domestic consumer would take the trouble to keep a balance-sheet, setting the diminished butcher's bills against the cost of current, it could be proved every time to his own satisfaction that he was money in pocket at the end of the year. A further obvious economy is the diminished consumption of coal in the kitchen. The annual consumption of coal in a house of, say, £50 rental is about 15 tons, of which at least 10 tons are used in the kitchen. In providing for warming the kitchen and providing hot water for baths, &c., probably not more than four tons are required, thus showing a saving of six tons, representing (at prices in the Midlands) £4. 10s. per annum.

Users of electric cookers have soon discovered one grave defect, the absence of a quick-boiling kettle for small quantities of water. The ordinary consumer will not wait 10 minutes while the hotplate is warming up, and a further 7-10 minutes for the water to boil, when a kettle on a gas-ring can be boiled up in 10 minutes. To meet this difficulty a neat arrangement has recently been devised by Mr. Berry. A specially-shaped kettle is used, into which can be inserted a cartridge element (Fig. 1). The resistance strip is wound on a copper tube covered with a layer of pure mica, the connecting leads consisting of four strands of the element laid along the tubes in longitudinal grooves, so as to prevent lumps. Over this strip is wound two layers of thin copper tape, insulated from the winding by pure mica. A brass cap, fitting tightly on the tube and then opened out to slip over the tape, finishes one end; and at the other end is a brass terminal box, which carries the contact pins. When all the parts are assembled the whole apparatus is soldered up solid and watertight. A smaller tube is fixed down the centre of the main one into the plug, closing the end carrying the terminal box, and has holes at the bottom end; the other end carries a small "umbrella." This arrangement allows the water to circulate inside, the "umbrella" preventing the overflowing stream from interfering with the cold water entering. The loading is 1,200 watts, and this can be assisted by standing the kettle on the hot-plate. With an initial temperature of 40° Fah. three pints of water can be boiled in six minutes with 2,000 watts, at an efficiency of over 98 per cent.

The usual practice with gas undertakings is to let apparatus out on hire at 10 per cent. of the net cost of the outfit. This course has been adopted in Derby with electric cookers. The rentals charged are: For outfit, including "duplex" cooker, extension heater, and oven, 4s. per quarter; including griller and grease pan, 4s. 3d. per quarter; additional extension heater, 1s. 4d. per quarter. The small utensils used with the hot-plates are sold outright at prices approximately 10 per cent. above the net cost. The consumption of energy, at any rate, with the "bright" oven, usually amounts to 1 to 1½ units per person per day the lower figure may be obtained by strict economy, and at 1d. per unit the author believes this will compete with gas at 2s. 6d. per thousand cubic feet. With electricity at ¾d. or ½d. per unit, as is now charged in some towns, there is no question of the economy of electric cooking.

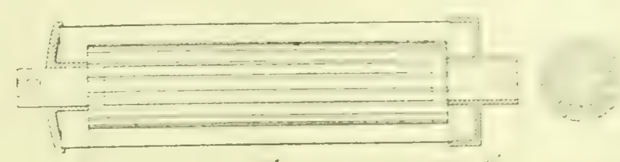


FIG. 2. SECTION OF "[illegible]" ELECTRIC [illegible].

Warming of Rooms.—To some engineers, the warming of rooms offers an even more attractive problem than electric cooking, on the ground of the much lower selling and hiring prices of radiators; on the other hand, it must not be forgotten that they are very little required in summer, whereas

* Abstract of paper read before the Birmingham section of the Institution of Electrical Engineers.

the cooker is an all-the-year-round load, and is even more used in summer than in winter. It is difficult to lay down definite rules for the amount of electrical energy required for warming rooms, as it depends on so many factors, such as the window area and the user's idea of fresh air. For proper ventilation it is necessary to change the air of a room three times an hour. A good rule, based on hot-water practice is: —

$$\text{Kilowatt capacity} = \frac{(30\,A + 8\,B + \times\, u\,C)\;20{\cdot}4 \times l}{60 \times 60 \times 1{,}00},$$

Where A = number of square feet of window surface; B = number of square feet of wall surface; C = number of cubic feet of air in room; n = number of times air is changed per hour; l = number of degrees Fah. the air has to be raised in temperature. Thus a room 30ft. × 16ft. × 10ft., with three windows 3ft. 6in. × 6ft., would require 2·5 kw. to raise the temperature 20°; and a room 16ft. × 14ft. × 10ft. high, with one window 5ft. × 3ft. 9in., would require 1·3 kw. to raise the temperature 20°.

The electric radiator is clean, portable, cheerful, and instantaneous. The present difficulties are the innate conservatism of the householder, the necessity for two sets of wiring where ordinary flat rates of charging are in force, and the running cost where the radiators are used for long hours at the ruling price of 1d. per unit.

It is unnecessary to point out the absurdly low efficiencies of coal and gas fires owing to the necessity of providing for the disposal of the products of combustion. In the aggregate, the smoke nuisance from domestic chimneys is far more serious than from factory chimneys, and if more attention were paid by the municipal authorities, as it should be, to the prevention of smoke from private houses, an enormous impetus would be given to electric heating.

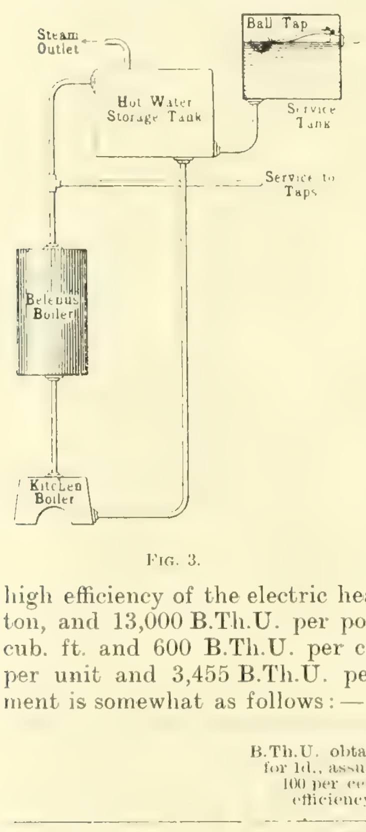


FIG. 3.

Water Heating.—Water heating is, financially, by far the most difficult problem to deal with. Comparing coal, gas, and electricity on a calorific basis, the case for electricity appears to be hopeless, and its only salvation lies in the exceedingly high efficiency of the electric heater. Taking coal at 17s. per ton, and 13,000 B.Th.U. per pound, gas at 2s. 6d. per 1,000 cub. ft. and 600 B.Th.U. per cub. ft., and electricity at 1d. per unit and 3,455 B.Th.U. per unit, a comparative statement is somewhat as follows: —

	B.Th.U. obtainable for 1d., assuming 100 per cent. efficiency.	Efficiency in practice (say)	Useful B.Th.U. obtained for 1d.
Coal	142,750	10 per cent.	14,275
Gas	20,000	50 ,, (with geyser)	10,000
Electricity	3,455	90 per cent.	3,109

The author has seen tests made by an independent and reliable authority in which an efficiency of over 97 per cent. has been gained with a Belling electric geyser. The three most notable attempts to solve this problem are the Therol heater, the Belenus boiler, and the Belling geyser. In the first mentioned, the heating coil is embedded in a block of cast iron, providing a large degree of thermal storage. The capacity of the coil varies from 50 watts to 900 watts in the large sizes, and the hot water at 110° Fah. varies from 5 galls. to 135 galls. per day. The apparatus is the essence of simplicity, and provides a demand of 100 per cent. load factor, obviously forming a most desirable load, even at an exceedingly low price for electrical energy. An interesting installation of Therol heating in a private house in London may be mentioned. The household consists of seven persons, including two children. A 300-watt heater is installed with an auxiliary 1,000-watt unit, also a small 200-watt heater for the kitchen and scullery; there are three baths required per day, and, of course, hot water continually for other purposes. This installation has replaced a gas circulation heater. After one year the consumer found a saving of 7½ per cent. in actual payments, as well as a saving in deterioration of decorations. The price paid for current, based on £1 per kilowatt installed, plus ½d. per unit, came to about 0·65d. per unit.

The Belenus boiler (Fig. 2.) consists of a column of cast-iron provided with deep corrugations along the bore in order

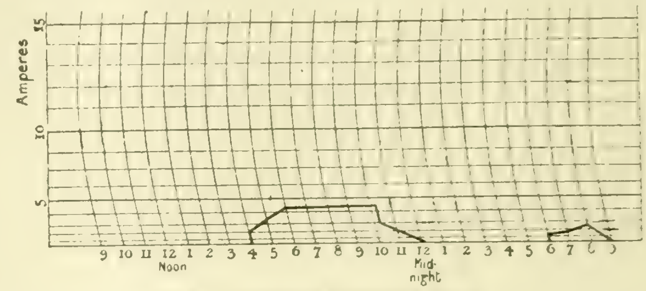


FIG. 4. LIGHTING RECORDER CHART.

that the surface in contact with the water may be as great as possible, and with a number of deep slots on the outer surface in which the elements are embedded. These elements are plain strips of inert material, wound with heavy gauge wire run at a low current density, and are insulated by pure mica from the column. There is at least ½in. of cast iron between the elements and the water. The boiler, when arranged as a circulation heater, is always full of water, and the elements can never attain a high temperature or burn out. The boiler is installed in exactly the same manner as the old-fashioned saddle-back kitchen boilers, iron pipes being run from the top and bottom to the top and bottom respectively of the household hot-water tank. In old houses the electric boiler can be fitted in the riser to the tank, and employed to reinforce the kitchen boiler, and to take its place in the summer. The boiler is provided with a steel case and air lagging around the column. A high efficiency is attained when sheet lagging is fitted over this, and the pipes are lagged in the usual manner. The Belenus boiler can be installed in the kitchen, scullery, or any convenient out-of-the-way position; it can be fixed in series with the kitchen boiler, and simply switched on when the fire is not in use (Fig. 3).

The Belling geyser is somewhat similar in operation to the Belenus boiler, but it has in addition a control gear by which the electric switch and water supply handles are interlocked, so that it is impossible to switch on the current before the water, or to turn off the water without first switching off the current. Independent tests show an efficiency as high as 98 per cent. The heavy loading of 10 kw. is, however, an objection.

Undoubtedly the cheapest solution of the problem, at the present time, would be to discard the kitchen fire altogether;

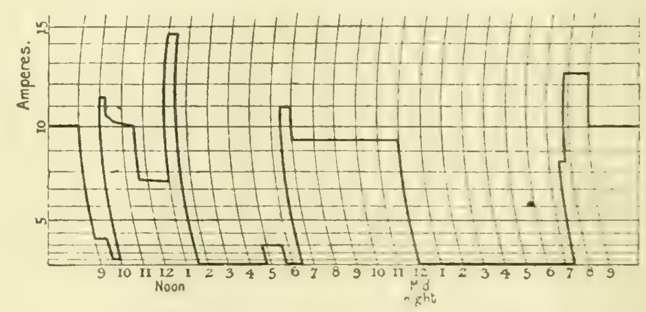


FIG. 5.—HEATING RECORDER CHART.

to fix a coke stove of the "Ideal," or other type, for hot-water purposes, and to cook by electricity. A small "Ideal" boiler will supply 50 galls. of hot water per hour at, say, 120° Fah. for 30,000 B.Th.U. per hour, or, say, ¼d., a result not yet approached by any other method.

Cost of Supply.—This is, after all, the most important question. Supply engineers are now realising that the application of the Hopkinson system of charging in one form or

another is a necessity for domestic supply, if heating and cooking by electricity are to make rapid headway. The two best-known modifications are the "Norwich" system and the "Telephone" system. In the former the initial charge is a percentage of the rateable value, plus a low charge for current. At Norwich the rate is 12½ per cent. of the rateable value, plus 1d. per unit for all current consumed. At Bradford the rate is 15 per cent., plus ½d. per unit, and at Sunderland 10 to 15 per cent., according to the size of house, plus ½d. per unit. In the "Telephone" system the initial charge is based on the connected lighting load. In Marylebone the charge is based on 70 per cent. of the connected lighting load at £14 per kilowatt, plus 1d. per unit. It appears to the author, however, that in this system the consumer depends on the caprice of the inspector, and is subject to domiciliary visits, which may be resented.

The preponderance of heating over lighting units may be emphasized by a comparison of the curves Figs. 4 and 5, which are the lighting and the heating recorder charts for a certain house in Derby. At Southampton, Mr. H. F. Street informs me that prior to 1910 only 20 radiators were in use. Since the institution of a flat rate of ½d. per unit, however, about 1,000 radiators have been connected, and more than half of these are of the 2 kw. type. At Luton, Mr. W. H. Cooke has sold about half a million units for heating during the last year at a low price. It is obvious therefore, that once a satisfactory price can be adopted the load will follow, as a matter of course.

COMPARATIVE TESTS OF LOCOMOTIVE BOILERS

FITTED WITH JACOBS-SHUPERT AND RADIAL STAY FIREBOXES.

(Concluded from page 307.)

TESTS, SERIES "B."

THE boilers having been restored to their normal conditions after the conclusion of the tests in series "A," the tests of series "B" were instituted. They were first run using Scalp-Level coal as fuel and without the presence of an arch in the firebox. This series was followed by two tests in which Dundon coal, a long-flame gas coal, was used. After this the brick arch was added to the firebox and the programme of tests was practically repeated. The tabulated statement Table III. covers the more important results which were obtained from the entire series.

Results of Tests without the Brick Arch in the Firebox.—These are represented in Table III. by tests 201 to 302, inclusive. The series includes five tests of the Jacobs-Shupert boiler and four tests of the radial-stay boiler when fired with Scalp-Level coal, and one test of each boiler when fired with Dundon coal. The efficiency of a locomotive boiler is highest when the power developed is least. For example, referring to the first test (201), it will be seen that when the Jacobs-Shupert boiler was fired with 1,315lbs. of moisture-free coal per hour it evaporated 15,293lbs. of water per hour; evaporated 5·08lbs. of water per square foot of heating surface per hour; evaporated 11·01lbs. of water per pound of coal; developed 443 h.p.; developed an over-all efficiency of 71·86 per cent.; and developed an efficiency, excluding the grate, of 79·75 per cent.

The precise effect produced by increasing the load upon a boiler is well shown by the values of the heat balance for the several tests run with Scalp-Level coal. For example, tests 201, 202, 204, and 205 represent in the order given an increased rate of power. A statement of conditions and results is as follows:—

Test number	201	202	204	205
Pounds of coal fired per hour	1,389	3,419	5,930	16,314
Thermal units for each pound of coal:—				
Absorbed by water in boiler	10,687	9,327	7,532	7,388
Lost by moisture in coal	48	34	37	33
Lost by moisture in air	49	53	114	64
Lost by hydrogen in coal	486	497	500	514
Lost by smokebox gases	1,979	2,731	3,992	4,675
Lost by incomplete combustion	78	-	-	-
Lost by cinders passing up stack	153	851	1,078	1,012
Lost by combustible in ash	1,187	679	291	185
Lost by radiation and unaccounted for	205	547	881	783
Total B.T.U. per pound of coal	14,872	14,719	14,425	14,654

By comparing the values in the horizontal lines, the changes resulting from changes in the rate of power may be seen. First, it will be observed that the number of thermal units absorbed by the water in the boiler becomes smaller with each succeeding test. The loss thus sustained is accounted for by the increased amount of heat which goes off with the smokebox gases and in the form of combustible material which passes out of the stack as cinders.

The evaporative performance of the boilers in terms of pounds of coal fired per hour is shown by Fig. 6. In this figure the heavy circles represent tests with Dundon coal, and the lighter circles tests with Scalp-Level coal. Tests upon the Jacobs-Shupert boiler are indicated by the plain circles, while the tests on the radial-stay boiler are indicated by combined circles and crosses. The diagram represents all results obtained. Tests 301 and 302 were run with Dundon coal, all others with Scalp-Level coal. The long straight line represents the tests of the Jacobs-Shupert boiler when using Scalp-Level coal. This line also represents fairly well the results obtained from the radial-stay boiler, which are marked by crosses. Dundon coal gives a higher evaporation than Scalp-Level coal. A parallel line is drawn through the two points representing the results obtained from the two boilers when fired with Dundon coal.

Results with a Brick Arch in the Firebox.—Upon the completion of tests 201 to 302, inclusive, both boilers were equipped with brick arches. Thus equipped, tests 401 to 501, inclusive, were run. A summarised statement of the actual

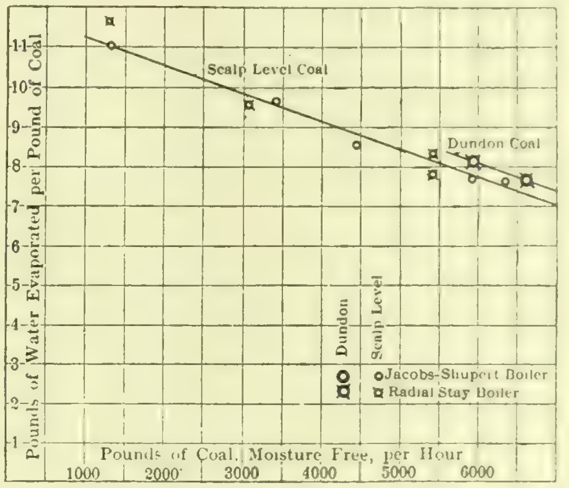


FIG. 6. WATER EVAPORATED PER LB. OF COAL, TESTS WITHOUT ARCH

values derived from these tests appears in Table III., and the comparative performance of the two boilers is set forth by Fig. 7. In the latter figure, the long straight line is drawn to represent as nearly as possible the points shown by circles, which are those of the Jacobs-Shupert boiler when fired with Scalp-Level coal. This line also represents fairly well the points located by crosses, which indicate results obtained from the radial-stay boiler. The crosses fall lower than the circles which determine the location of the line. Only one test representing Dundon coal is of record in this group, and this (501) is a test of the Jacobs-Shupert boiler at the highest rate of power developed during the series. In this test the firing was at the rate of 6,553lbs. of moisture-free coal per hour. This rate of firing resulted in a rate of combustion equalling 119·38lbs. of coal per foot of rate per hour; an evaporation of 57,564lbs of water per hour, or the equivalent of 19·13lbs. of water per foot of heating surface per hour; the development of 1,669 boiler horse-power, or the equivalent of one boiler horse-power for each 1·8ft. of heating surface; an evaporation per pound of coal, notwithstanding the high rate of power developed, of 8·78lbs. of water; and the maintenance of an over-all boiler efficiency of 65·34 per cent., and of the boiler, exclusive of the grate, of 67 per cent.

It is unusual for boilers to be driven to such rates of power. At the Purdue locomotive testing plant, as a result of its first fifteen years of operation, the highest rate of evaporation made of record was 14·45lbs. of water per foot of heating surface per hour, obtained August 7th, 1905, by the use of Youghiogheny coal. At about the same time the report of the Pennsylvania R. R. Company of the St. Louis tests was issued, by which it appeared that the New York Central locomotive

No. 3,000 had, while on the testing plant, been forced to a rate of 16·34lbs. per foot of heating surface per hour, which was the maximum for that celebrated series of tests. It is in comparison with these record-breaking performances that the rate of 19·13lbs. obtained for the Jacobs-Shupert boiler at Coatesville is to be considered. So far as is known it represents the highest rate of power to which any locomotive boiler has been driven.

The conclusions to be drawn from the tests of series B concern evaporative efficiency and capacity. The results show that the Jacobs-Shupert boiler and the radial-stay boiler, under all the various condition of the tests, operate at practically the same efficiency. There are indications that under very high rates of power the Jacobs-Shupert boiler has some slight advantage. Two boilers of the same efficiency will generate equal amounts of steam for equal quantities of fuel consumed. Relative steaming capacity is in the case of such boilers a matter of relative coal-burning capacity. The superior strength of its firebox allows the Jacobs-Shupert boiler to be fired to very high limits of power without injury. Its strength thus becomes an indirect factor in extending its capacity. In this respect, the capacity of the Jacobs-Shupert boiler excels that of the radial-stay boiler.

Low Water Tests, Series "C."

The arrangements for the low water tests were described in our issue of July 19th last. The Jacobs-Shupert boiler was the first to be tested. The test was officially begun at 1-48 p.m. The water left the crown sheet at 1-49$\frac{1}{6}$ p.m., and its level steadily declined for 34$\frac{1}{6}$ minutes when it had fallen to the bottom of the special water glass 25$\frac{1}{2}$in. below the crown sheet. The steaming capacity of the boiler declined as the water-level fell. In the beginning, besides the steam passing out of the exhaust pipe, a large volume was discharged by the safety valves, but with the fall of water-level the amounts thus discharged diminished until the valves ceased to open. The pressure then declined, the blast became less effective, the draught weakened, and the fire became smoky. Twice the throttle opening was increased to stimulate the draught, but the pressure ran down the more rapidly. Fifty-five minutes after the beginning of the test upon the Jacobs-Shupert boiler the water-level had fallen to a point where the barrel of the boiler was less than one-fourth filled, and the capacity of the boiler to generate steam had so diminished that the draught conditions with which the test started could no longer be maintained. The oil supply had not been changed and clouds of black smoke issued from the stack. When the steam pressure had fallen to 50lbs. the low water test of the Jacobs-Shupert boiler was ended. It had been boiled nearly dry and no failure had occurred.

Upon the termination of the test of the Jacobs-Shupert boiler, fire was started under the radial-stay boiler. Approximately half an hour was required in which to bring this boiler to a condition of operation identical with that which defined the operation of the Jacobs-Shupert boiler, after which the test was started, and the record kept in the same way as before. When the water had fallen in the water glass to a point which was 14$\frac{1}{2}$in. below the crown sheet, 17$\frac{3}{4}$ mins. after it had left the level of the crown sheet, the boiler failed by the pocketing of a large area of the crown sheet, embracing a total of 88 stay and crown bolts. In the Jacobs-Shupert boiler the feed was on for a total of 2$\frac{1}{2}$ mins. during the first 5 mins. of the test, after which the whole process was simply one of boiling away the water contained by the boiler. In the radial-stay boiler the feed was on 2 mins. during the first 7 mins. of the test only. Both boilers lost water at substantially the same rate for the first 22$\frac{1}{2}$ mins. of the test. At the end of this time, the radial-stay boiler had failed, but the Jacobs-Shupert boiler continued in operation without diminution in the amount of oil burned for 30$\frac{1}{2}$ mins. longer. The radial-stay boiler failed in less than 18 mins. after the water was observed at the crown-sheet level. The Jacobs-Shupert boiler was operated 53 mins. after the water was observed at the crown-sheet level.

The appearance of the Jacobs-Shupert boiler at the end of the test was as though ready for further service. The firebox was composed of eleven sections. Those most affected disclosed a curvature which dropped $\frac{1}{2}$in. more than that which was originally given them. The change in contour, while not entirely regular, disclosed no evidence of a disposition to develop pockets or to local failure by blowing out. It is considered noteworthy that, notwithstanding the high temperature to which this firebox was subjected, the colour of newly-heated metal nowhere extended around the section to a stay sheet, nor was there any point on the caulking edge of the stay sheet which had been heated beyond that temperature which resulted in the reddish brown colour. Nothing in the appearance of the sections or of the stay sheets indicated the presence of the least leak through the crown. The tube sheet was found to retain very nearly its original shape. On either side of the centre and near the middle of the heated

TABLE III.

Designation of Test.	Kind of Coal.	Moisture Free Coal per Hour pounds.	Moisture Free Coal per Sq. Ft. Grate per Hour pounds.	Equivalent Evaporati'n per Hour pounds.	Equivalent Evaporati'n per Sq. Ft. Heating Surface per Hour pounds.	Boiler H.P. Developed.	Ratio of Heating Surface to H.P. Developed.	Equivalent Evaporati'n per Lb. of Coal, Moisture Free, Fired.	Overall Efficiency.	Efficiency Excluding Grate.
WITHOUT ARCH IN FIREBOX.										
B-201-J	Scalp Level	1,389	24·45	15,293	5·08	443	6·8	11·01	71·86	79·75
B-202-J	Scalp Level	3,419	60·18	32,861	10·92	953	3·2	9·61	63·37	71·51
B-203-J	Scalp Level	4,467	78·63	39,964	13·28	1,158	2·6	8·95	58·29	63·96
B-204-J	Scalp Level	5,930	104·38	46,045	15·31	1,335	2·3	7·77	52·23	58·26
B-205-J	Scalp Level	6,314	111·14	48,070	15·98	1,393	2·2	7·61	50·41	55·36
B-206-R	Scalp Level	1,282	22·04	14,952	5·01	433	6·9	11·68	76·62	79·37
B-207-R	Scalp Level	3,051	52·46	29,108	9·75	844	3·5	9·54	62·26	66·41
B-208-R	Scalp Level	5,397	92·80	44,658	14·97	1,294	2·3	8·28	54·64	57·67
B-209-R	Scalp Level	5,427	93·31	42,404	14·21	1,229	2·4	7·81	52·25	54·39
B-301-J	Dundon	6,631	116·72	50,617	16·83	1,467	2·1	7·63	56·54	57·96
B-302-R	Dundon	5,484	94·29	44,383	14·87	1,287	2·3	8·09	59·23	60·26
WITH ARCH IN FIREBOX.										
B-401-J	Scalp Level	1,367	24·06	15,683	5·21	455	6·6	11·47	74·82	78·85
B-402-J	Scalp Level	2,656	50·27	30,484	10·13	884	3·4	10·67	69·79	75·50
B-403-J	Scalp Level	5,386	94·81	45,701	15·19	1,325	2·3	8·49	56·76	61·12
B-404-J	Scalp Level	5,887	103·63	51,759	17·21	1,500	2·0	8·79	57·90	61·27
B-405-R	Scalp Level	1,321	22·71	15,452	5·18	448	6·7	11·70	76·50	80·72
B-406-R	Scalp Level	2,926	50·31	29,953	10·04	868	3·4	10·24	67·42	72·10
B-407-R	Scalp Level	5,069	87·16	44,788	15·01	1,298	2·3	8·84	58·87	62·43
B-501-J	Dundon	6,553	115·35	57,564	19·13	1,669	1·8	8·78	65·34	67·01

zone, where in the design of the boiler there is a considerable area unsupported by tubes, the plate was bulged to the extent of ¼in. At the crown of the tube sheet a small leak had developed. The joint at this point is made by riveting the first section of the firebox to the tube sheet with a copper caulking strip between. It is at the crown of this joint that the evidence of the leak appears. This leak, the only one to be found in the firebox, was so slight as not to have interfered with the normal operation of the boiler.

Within the highly-heated area of the tube sheet there were about 180 tubes. Naturally the upper tubes were most affected by the heat to which they were exposed. Four of the tubes were found to have collapsed just inside of the tube sheet, 14 others, making 18 altogether, were found pulled apart inside of the sheet. The weld between the tube and the sheet was not disturbed in any case. It is probable that, except in the case of those which collapsed, the actual rupture of these various tubes occurred in the process of cooling after the test had been finished. All other tubes were intact so far as their contact with the back tube sheet is concerned. All those within the heated zone were found deflected downward, the deflection varying from a comparatively small amount to an amount equal to the diameter of the tubes. The tubes which at the conclusion of the test were below the water line remained in their original straight condition.

The door sheet of the firebox was not greatly affected by the conditions imposed by the test. There was no distortion of this sheet and no evidence of leaking stay bolts. The arch tubes were not disturbed or affected by the test, and the arch at the conclusion of the test was, as already noted, in perfect condition. A review of these conditions indicates that as far as the firebox construction is concerned, the boiler at the conclusion of the test was in condition for further operation.

As the radial-stay boiler failed under the low-water test, the force of the explosion was sufficient to raise the rear of the boiler, to blow out the brick arch, to blow out the cast-iron pedestals, to disrupt the brickwork under the boiler, and to scatter fragments of all of these over an area 100ft. or more in radius. The boiler itself was lifted from its foundation and was moved forward a distance of about 8in., the rear swinging to the right. As the front end of the boiler slid forward on the support under the barrel, an extra heavy blow-off pipe was sheared. The button-headed stays in the crown sheet failed by the stays breaking inside of the sheet and the flat-headed stays pulled through the sheet. The sheet itself was found not to have ruptured or cracked, and, so far as could be determined, no button-headed stay pulled through the sheet, though the holes in the sheet were in many cases considerably elongated in direction of the maximum movement of the plate. The contents of the boiler were discharged through the openings vacated by the stay bolts, the aggregate area of which has been found to be approximately 186 sq. in.

It was observed that both side sheets with their staying were in perfect condition, no evidence of leaking stay bolts appearing; that the door sheet with its stays was in perfect condition; and that the tube sheet was in perfect form, the tubes appearing to be as secure as when originally welded thereto. Only a few tubes, variously estimated from nine to 18 in number, seemed from their colour to have been involved by the overheating. No tube was found which has been sufficiently heated to sag. Only a very small portion of the tube sheet was found to be overheated. The arch tubes were forced somewhat downward by the discharge of steam from the crown sheet, and the right-hand tube had been distorted sufficiently to develop a leak in the tube sheet. That the failure of the boiler was not more disastrous is to be accounted for in the superior character of the materials and workmanship employed in its construction.

The preceding description of the breaking down of the radial stay firebox is thought to be significant in that it confirms the experience in practice on the road. The firebox tested was new; there was no accumulation of scale upon it. It had not been weakened by strains induced by long service, and it had every chance to present the maximum resistance to failure to be expected of that type of construction which it represents. The facts show, however, that when, through the receding of the water level, the heated zone had extended downward sufficiently to include the upper portion of the crown and to take in only the upper rows of the tubes, this firebox failed, irrespective of the fact that it was new and in perfect condition, and possessed material advantages over the average radial-stay firebox in service.

CONCLUSIONS.

The general conclusions justified by these tests are that the design of the Jacobs-Shupert boiler is the result of a carefully studied development of pre-existing practice; that the design easily admits of a grade of workmanship difficult to attain in the construction of pre-existing types of locomotive boilers; that those features which are peculiar to the new construction are

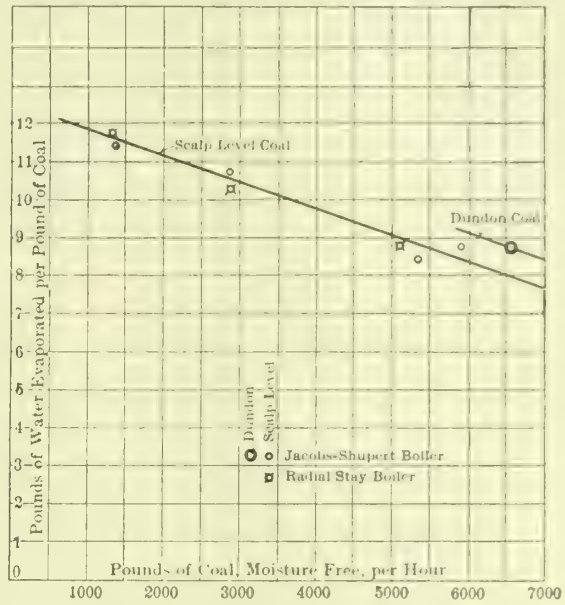


FIG. 7.—WATER EVAPORATED PER LB. OF COAL. TESTS WITH ARCH

such as tend to reduce cost in maintenance; that the evaporative efficiency of the Jacobs-Shupert boiler is the same as that of a radial-stay boiler of the same dimensions; that the steaming capacity of the Jacobs-Shupert boiler is, in general, the same as that of a radial-stay boiler, but that it may be forced without danger of injury to higher power; that the Jacobs-Shupert boiler presents nothing in its internal construction which can interfere with the usual movements of water over the heating surfaces, and that in the matter of circulation it possesses some advantage when compared with other types of locomotive boilers; that the superior strength of the Jacobs-Shupert boiler under low-water conditions permits it to endure overheating without failure for long periods of time, where the normal radial-stay boiler quickly fails; and that where the overheating is so severe that it cannot be resisted, the result will be a blow-out and not a disastrous explosion.

ANNEALING MUFFLES.

A PAPER on "Annealing Muffles," was read by Mr. C. H. Wall, at a recent meeting of the Birmingham section of the Institute of Metals. Muffles, he said, were now made with smaller fireboxes and flues arranged to circulate heat along the sides and under the beds, the combustion thus being made more perfect, while by enveloping the muffle with heat a larger amount of work was done with a corresponding reduction of fuel. Cross-fired muffles were got ready for work much more quickly than end-fired muffles, and a more regular temperature could be maintained. The best type of muffle was so arranged that the flame, after passing over the bridge and bed, entered a series of port holes of graduated size opposite the firebox. The waste gases, after passing the ports, were led into a flue under the bed of the muffle, and travelled round two or three times, according to the width of the muffle, before finally leaving for the stack. A large field was still open for improved economical appliances, especially in the introduction of gas firing. At present, 1·7 to 2 cwt. was used in the gas-producer per ton of iron heated, as compared with one ton of coal formerly used to heat up $1\frac{2}{3}$ tons of iron, but the theoretical possibility of one ton of coal heating 36 tons of iron to the welding temperature was still far from being attained. It was satisfactory to note that existing muffles had reduced the fuel consumption by from 30 to [illegible] per cent

IMPROVEMENTS IN BORING AND FACING MACHINES.

THE accompanying illustrations show several improvements in revolving facing machines of the type in which a tool-box-carrying head-stock carries a tool-box so mounted thereon as to be adapted by automatic feed gear to be traversed transversely to the axis of rotation at a rate which can be varied relatively to the rate of rotation of the carrier, recently patented by Messrs. H. W. Kearns & Co., Ltd., Broadheath, Manchester. The machine is so designed and constructed

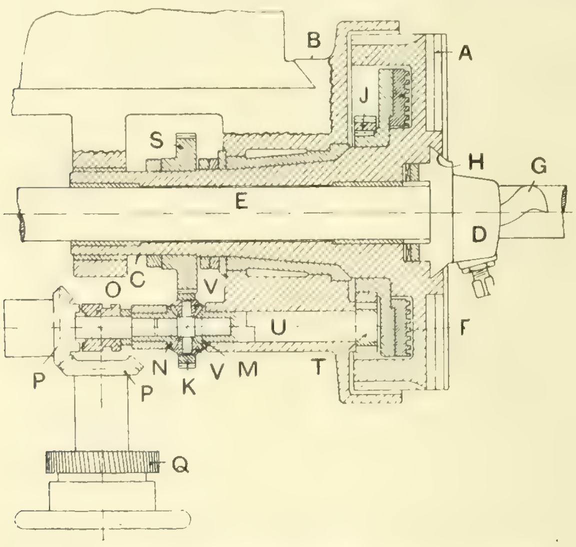


FIG. 1.—IMPROVEMENTS IN BORING AND FACING MACHINES.

that the operations of boring and facing can be simultaneously and independently performed. For this purpose the spindle which supports the head-stock is bored to receive a boring bar and the tool-box is of fork-shaped construction, the branches of which are sufficiently separated to receive the boring bar between them, so that whilst not interfering with the boring operation, it is able to receive a considerable length of radial support within a recess formed in the face of the head-stock. Means are also provided whereby the gear normally provided for varying the rate of operation of the machine can be caused to co-operate with the transverse feed movement of the cutting tool and thereby avoid the provision of a special set of speed gears for varying the rate of transverse feed movement.

Fig. 1 is a section taken through the axis of the tool-box carrier. Fig. 2 is a view showing the conformation of the fork-shaped tool-box, and Fig. 3 is a front view of the tool-box carrier. The tool-box carrier A has, formed integrally therewith, a hollow shaft C which is mounted in bearings provided in a head-stock B carried by the frame of the machine. Around the periphery of the carrier A spur-teeth are provided whereby, through the medium of a pinion not shown, the carrier is rotated by power transmitted through change-speed gear of usual construction, permitting the rate of revolution of the carrier A to be varied as desired. Diametrally across the face of the carrier a recess H of dovetail section is formed for the reception and guidance of a tool-box D. The tool-box D shown separately in Fig. 2 is of fork-shaped configuration, the width of the space between the two branches being sufficient to permit of the protrusion from the carrier A of a spindle E which fits the hole bored through the hollow shaft C of the carrier A. In a recess, provided within the back of the tool-box carrier A, is rotatably mounted a cam plate F in the face of which has been cut a spiral groove of involute configuration, a spur wheel J being secured thereto for the purpose of effecting the rotation of the cam plate relatively to the carrier A. Within the diametral recess, which contains the sliding tool-box D, grooves L are formed, on each side of the central orifice in the carrier, whereby portions of the spirally-cut cam plate are exposed to view and whereby projecting ridges R formed on the back surface of the tool-box can enter into engagement with the spiral groove which is formed in the face of the cam plate F. If, in such a construction, the cam plate F is caused to rotate relatively to the carrier A, the tool-box will be required to undergo a radial displacement across the face of A whilst partaking of its rotary motion. By such means a tool G, carried in the tool-box, will be enabled to perform a facing operation at any desired suitable speed, simultaneously with the performance of another cutting operation by a tool carried by the spindle E, which spindle can be driven at a selected speed which may bear no relation to that of the tool-box carrier A.

The rotation of the cam plate F relatively to A at a change-speed rate and reversible in direction, whilst A is being continuously rotated, is effected by gear wheels as follows: To the hollow shaft C of the carrier A is secured a driving spur wheel S. This wheel, through the medium of pinions K and T, connected and secured respectively to a spindle U, is geared to the spur wheel J of the cam plate F which is required to be driven. The connection of the pinion K with the spindle U is effected through the medium of a set of four bevel wheels. Two of these wheels V are mounted within the pinion K in a manner which will permit them to rotate about an axis which is diametrally situated relatively to the pinion, whilst partaking of the rotation of the pinion. The bevel wheels V engage on one side of the pinion K with a bevel wheel M which is clutched in a longitudinally separable manner to the spindle U. On the other side of the pinion K the bevel wheels V engage with a bevel wheel N which, through a clutch O, is adapted to be retained at rest or rotated in either direction. When the bevel wheel N is held at rest, the bevel wheel M and spindle U will make two revolutions with each revolution of the pinion K, and accordingly, if the ratio of J to T is twice that of S to K the cam plate F will be conveyed around on the carrier A without any motion relatively thereto, under which circumstances the tool-box D will undergo no radial motion. By means of the bevel wheel N an independent rotation in either direction can be superposed on the rotation of U which is due to the above-described set of gear wheels. As shown in the drawing, the bevel wheel N can be driven through the bevel wheels P, clutch O, and worm wheel Q from the main feed-box of the machine. Thus the main feed-box of the machine, which determines the rates of travel of all the working parts of the

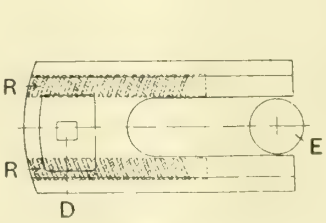


FIG. 2

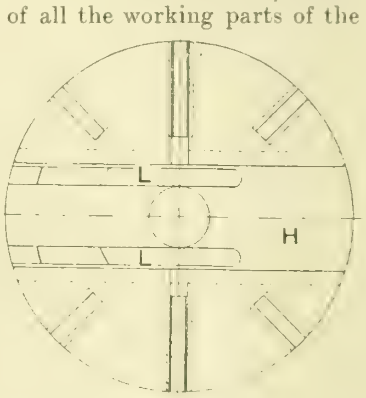


FIG. 3.

IMPROVEMENTS IN BORING AND FACING MACHINES.

machine, including the rates of rotation of A and E, can be requisitioned to determine also the rate and direction of radial traverse of the facing tool G.

Association of Oil Engineers.—An association to represent oil engineering interests was decided on at a meeting recently held in London, when a committee, which includes Sir Fortescue Flannery, M.P., Sir Boverton Redwood, Mr. W. Bruce Dick, and Mr. D. A. Sutherland, was elected to take the necessary steps to bring the association into existence. It was pointed out at the meeting that at the present time oil engineers, in order to discuss subjects of technical interest to them, had to resort to other institutions. It was proposed therefore to form a representative association, which would be of a purely scientific character, interesting itself, as an institution, in the geological, chemical, engineering, and economic questions associated with the working and development of the petroleum industry. The provision of a library and bureau of information would also be undertaken and an attempt made to secure correspondence from every oilfield. The constitution would follow the lines of that of other institutions, and the management would be vested in a president, vice-presidents, and a council. It was proposed to hold two conferences for the reading and discussion of papers in each year.

CABLES FOR SHAFTS AND MINES.*

BY E. KILBURN SCOTT, A.M.INST.C.E., M.I.E.E.

AMONGST other points discussed in this paper the following receive special emphasis:—

(*a*).—Cables for shafts of mines differ from those for other situations, because the question of weight is such an important factor. In order to reduce weight, the cables should be worked at high tension, and the usual weighty accessories of cables, such as lead and armour, be minimised or dispensed with. Although aluminium has not been used for shaft cables there is every reason to suppose that this light metal would be found distinctly advantageous. Contrary to the general supposition, aluminium is much stronger from the point of view of supporting its own weight than is copper.

(*b*).—All metal-work which is continuous from top to bottom of a shaft should be utilised as the earth return. There is nothing in the Revised Rules against this being done. In any event, the cross-section of the armouring of a high-tension cable is likely to be too small to properly earth the low-tension underground feeders. Even where it is not convenient to use existing metal-work, it would be very much cheaper to suspend wire ropes in the shaft for the earth return than to place the same amount of metal round a cable as armour.

(*c*).—The marked success which has followed the use of cab tyre rubber as a mechanical protection on cables subjected to moisture and hard wear and tear, points to its being also a very suitable material for cables permanently installed in shafts. Further, a sinking cable must necessarily be insulated with rubber for the required flexibility, and the addition of tyre rubber in place of the special flexible armouring seems a reasonable proposition. By placing the winch in one or more insets as the shaft descends the length of sinking cable can be limited to that at which a cable without armour is feasible.

(*d*).—Hitherto casing has always been made of sawn planks, the joints of which are difficult to keep tight. The writer suggests the use of telegraph poles sawn longitudinally and having the joints between the halves closed by steel hoops. Such casing would be cheap and easy to erect, and it would form a complete protection to the enclosed cable. Regarding preservatives for casing and cleats, it is pointed out that saccharine impregnated into the wood is better than tarry or other chemical substances, because it has no action on insulations or metals. Also, when impregnated along with arsenic it is a complete solution of the white-ant difficulty which is so troublesome in mining work overseas.

Shaft cables can be conveniently divided into: (1) Cables which are permanently installed for the main supply of power; and (2) cables which are temporarily installed for sinking a shaft and which have to be moved at intervals. The bulk of this paper naturally deals with class (1), but at the end some space is devoted to considerations regarding class (2). Hitherto there has been a tendency to assume that cables suitable for underground roads are also the best to use in shafts. It can easily be shown, however, that the conditions are entirely different. Underground cables, for example, are always liable to injury from falls of roof and side, or by being run into by derailed tubs. The workmen may also handle underground cables for almost every yard of their length; also where ponies are used there is a chance of the animals trying to electrocute themselves. Shaft cables, on the other hand, cannot be handled by the men, and they are capable of much more permanent installation. The only possibility of mechanical injury is when something falls down the shaft, and, as a matter of fact, that chance of injury is a remote one, because a shaft cable only occupies about $\frac{1}{2000}$ part of the area of the shaft. Underground cables are provided with armouring, first as a mechanical protection, and second, to provide a convenient earth return. On underground roads there is no other metal that will serve the purpose of an earth return, but in a shaft, the case is generally quite different, for there are cage guide ropes and pipe lines which can be used.

The question of relying on the armouring of shaft cables as the earth return becomes more and more important every year, due to the tendency to transmit energy into a mine at higher tensions. The voltage in the main underground feeder may be only a fifth of that in the shaft, and naturally, the sectional area is much greater. Now, according to the Rules, the armouring of the low-tension cables must have a conductivity of at least 50 per cent. of one of the low-tension conductors; consequently any armouring there may be on the high tension shaft cables will be much smaller than the cross-sectional area of the armouring of the underground cables.

Some time ago the writer discussed with Mr. Robert Nelson (H.M. Chief Electrical Inspector of Mines), the question of using ropes and pipes in the shaft as an earth return. The point raised was more particularly whether the cage guide ropes in a certain shaft could be used, for the cables already installed were unarmoured. Mr. Nelson's reply was to the effect that there was nothing in the Rules to make the use of cage guide ropes illegal, the Rule merely asking that the earth connection shall be constantly maintained. Even where steel guide ropes or water pipes are not available, as, for example, in the case of an upcast shaft, there is no reason why old ropes should not be suspended in the shaft to

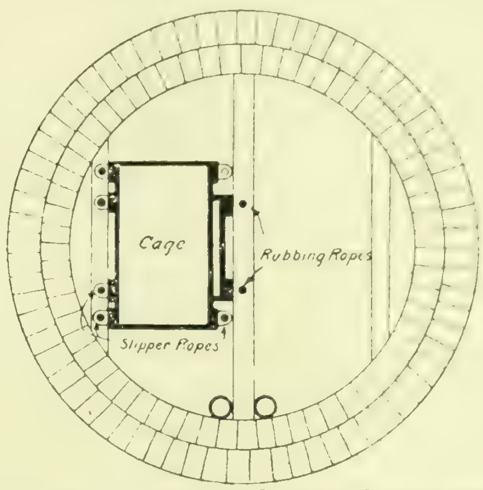


FIG. 1.—SKETCH SHOWING CAGE ROPES AND PIPES IN SHAFTS.

provide the earth return. A haulage rope, which originally cost £50, may be worth only £5 when unfit for haulage, yet it would serve quite well as the earth return in a shaft and take the place of armouring on the cable, which armouring might easily cost several times as much as the original rope. When stranded on to an insulated cable as armour, the steel wire sells for considerably more than it does when made up into a rope. It is easily seen that this must be so, because in order to lay the wires, a heavy and somewhat delicate cable has to be passed through the stranding machine, whereas in the case of a rope the wires are merely stranded on to a hemp core. Another argument in favour of using whatever metal there may be in the shaft for the earth return is that it is advisable to have several paths to earth so that if one should become discontinuous there are others to fall back upon. It is also just as well to earth all metal in a shaft as a further safeguard against shock.

To show how much metal there may be available, the shaft of the Frickley Colliery Company, near Doncaster, may be instanced: It is 23ft. diam., 670 yards deep, and contains 14 ropes, disposed as on Fig. 1. They are steel lock-coil ropes, $1\frac{1}{2}$in. diam., 12 being slipper ropes and two rubbing ropes, the latter being common to both cages. The headgear is of steel, and the conductors are bolted on to three girders which cross the top. All the ropes go down into the sump and are weighted with cheese weights to about 8 tons on each. The present earth plates are in the same sump. There is a pump in the shaft on a seam 280 yards down the shaft, and a 6in. range of piping delivers the water to bank. Another range, 5in. diam., feeds the pump with compressed air when it is not running electrically. From these particulars it will be seen that the total cross-section of steel and iron in the shaft is about as follows:—

	Sq. in. area.
14 steel ropes, each $1\frac{1}{2}$in. diam., say	20
Water pipe 6in. diam., say	6
Compressed air pipe 5in. diam., say	4
	30

* Abstract of paper read before the Association of Mining Electrical Engineers, February 7th, 1913.

Taking the relative conductivity of copper and iron as being, say, 6·5 to 1, it means that the iron in the shaft is equivalent to a copper conductor $\frac{30}{6\cdot5} = 4\cdot6$ sq. in. in area, or the ropes only are equivalent to a copper conductivity of $\frac{20}{6\cdot5} = 3$ sq. in. area.

It happens that the cable in this shaft consists of a double-armoured three-core paper-insulated cable for 3,000 volts which is slung from the top and supported every 50 yards by clamps bolted to the side of the shaft. The area of the steel armouring is about 2 sq. in., or only about one-tenth of the area of the wire ropes already in the shaft. For a cable measuring 3in. diam. over the jute serving, the cost of double-galvanised iron wire armouring, with compounded jute serving under and over the armour, is £420 per mile. Therefore the cost of the armouring of the above cable 670 yards long is about £160, on to which must be added the cost of erection and cleating of the extra heavy cable.

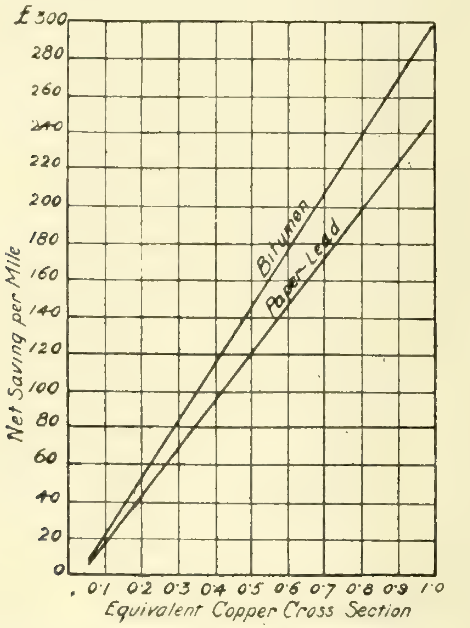


FIG. 2.—APPROXIMATE SAVING ON THE NET COSTS OF BITUMEN AND PAPER-LEAD L.T. ALUMINIUM FEEDERS, BASED ON COPPER WIRE AT 10½d. PER LB. AND ALUMINIUM WIRE AT 11½d. PER LB.

Even if there was no other metal in the shaft, as might be the case in, say, an upcast shaft, then it would be an easy matter to install an old steel rope to act as the earth circuit, and the cost might be put down at, say, £15, possibly one-tenth of the cost of equivalent metal when used as armouring of a cable. In other words, if one must install metal in the shaft for the specific purpose of providing an earth return, then to do so in the form of armouring on a cable is about as expensive and roundabout a way as could well be devised.

Under the new Rules the "conductivity of the armouring must be 50 per cent." of the conductor enclosed, and if single-armoured cables are used for continuous current, then the armouring must have 25 per cent. of the conductivity of the conductor enclosed. Although these percentages are definitely stated, it is also required that the armouring must in addition comply with the Engineering Standards Committee's Regulations. Where the diameter over the insulation is large as compared with the diameter of the conductor, as, for example, for high-tension cables, then there is no difficulty in applying armour, the section of which will comply with the 50 per cent. rule as well as with Engineering Standards. When, however, the diameter over the insulation is small compared with the diameter of the conductor, as is the case with low-tension cables, then the 50 per cent. Rule requires more armour than is called for by the Engineering Standards. This matter appears to have been overlooked when drafting the Electricity in Mines Rules. If, as suggested, all metal existing in the shaft is made use of, then when cables are armoured, the armouring need only be that required for mechanical protection, and thus an amount less than the 50 per cent. mentioned in the Rules can be employed.

Along underground roads the armouring of a cable provides the best means of maintaining an earth connection, for although an old rope might be used, there is not the same incentive to see that it is kept continuous, and further, it is liable to be overlooked. It is quite a different matter with the ropes and pipes in a shaft, for the cage will not work at all unless the ropes are kept in good order and water cannot be pumped unless the rising main is continuous throughout. Even if an old rope is used as the earth return in an upcast shaft, there is never any suspicion of the continuity of that rope as there would be if it were laid along an underground road. The mere fact that it remains suspended means that it must be electrically continuous.

When possible it is best for a shaft cable to be in one length, because joints are not easy to make or to maintain in such a situation. The length of a cable depends to a considerable extent on its physical dimensions, its weight, and the size of the drums, &c., and other things being equal, it is much easier to supply the cable in greater length when it is without armouring than when it has armour. This is distinctly an advantage for shaft cables. For underground and surface cables it is a convenience to have joint boxes at fairly frequent intervals, because much time and expense may be incurred in localising a fault on a long length. But in a shaft there is always more or less water, and the first consideration is to minimise the number of joints.

Conductor.—In order to reduce the diameter of a cable, the conductors are often made of the sector or clover-leaf section. For a given voltage, sector conductors require a greater thickness of insulation than cables with circular conductors. As shown in Table I., the critical voltage appears to be about 3,000, and at 6,000 and over the sector conductor cable is more expensive and of about the same diameter.

TABLE I.—*Comparison of Round and Sector Conductors.*

Working pressure. Volts.	Sectional area sq. m/m.	Relative prices. Circular conductor.	Sector conductor.
700–1,000	3×25	100	103
700–1,000	3×35	100	99
3,000	3×25	100	116
3,000	3×35	100	108
6,000	3×25	100	148
6,000	3×35	100	130

The electric capacity of a cable is slightly higher with sector conductors. The cable is also stiffer, but for low voltages this is made up for by the fact that the sector cable is smaller in diameter. More of it can be wound on to a given size of drum. It may be of interest to give a rough rule for comparing the relative diameters of cables with round, sector, and D-shaped conductors. For a given voltage, if A represents the diameter of a round conductor, then 1·863 A gives the diameter of a three-core sector cable and 2·04 A the diameter of a four-core sector cable. A cable having a pair of D-shaped conductors has a diameter over the insulation of 1·636 A.

Aluminium.—Shaft cables differ from all other cables in that weight is a principal consideration, and other things being equal, it would be a distinct advantage to employ a light weight conductor. Although aluminium is clearly an ideal metal, the writer believes he is right in saying that it has not yet been used for shaft cables, and this is the more strange because it has been used successfully for ordinary feeders. That aluminium insulated cables are a commercial possibility is shown by the fact that feeder cables have been in use in this country for some years. The fear has been expressed that, owing to the capacity of aluminium cables, the increased effects of resonance may cause piercing of the insulation in case of a sharp break in the circuit, but so far nothing of the kind appears to have occurred with those companies which have aluminium cables in use. For extra high tensions aluminium has an advantage over copper in being of larger diameter. In the case of the underground feeder at the Bitterfeld for the Prussian State Railway, it was necessary to strand the copper cable on a steel core so as to obtain mechanical strength and increased diameter. With the aluminium feeder of larger diameter, this was not necessary.

Independent of its light weight, aluminium is a suitable metal for use in shafts, because it is unaffected by bad water. All boxes, &c., on battle-ships which are exposed to salt spray

are fitted with aluminium lids, and its acid-resisting quality is shown by the fact that receptacles for dipping nitric acid are made of aluminium. The metal is unaffected by sulphur, whereas copper has to be tinned to resist its action. The oxide which forms on aluminium is a good insulator, as is shown by the fact that field coils for tramway motors are being made up of bare aluminium wire. For this purpose the wire has a specially thick layer of oxide deposited on it by treatment with borax. The bath contains 50 parts alcohol, 60 parts of ammonia, and 100 parts of water saturated with borax, and the temperature is kept at 50° to 80° C., whilst a current of 0·05 amperes per square centimetre surface of the coil is passed for about 15 minutes. After being washed and dried the completed coil is taped round in the usual way, and it is of interest to note that the actual cross-section of the finished coil is no larger than a coil made of copper wire, although there are the same number of turns. One reason is

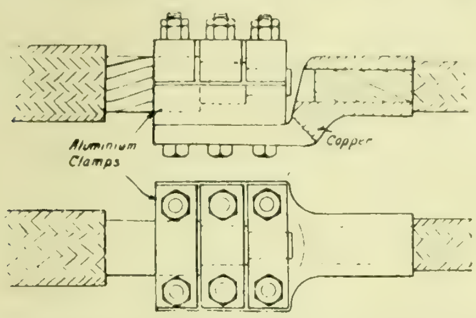


FIG. 3.—JOINT BETWEEN AN ALUMINIUM AND A COPPER CABLE.

that aluminium can be worked at a higher current density, and, being a solid mass of metal, the heat gets away more readily. The temperature coefficient is about 10 per cent. less than for copper. Bare specially-oxidised aluminium is being largely employed for winding the coils of lifting magnets because of greater durability under severe electric and mechanical stresses; also the reduced weight.

In order to fully appreciate the possibilities of using aluminium for shaft cables it may be well to give a few particulars of the metal. An aluminium conductor of the same resistance and length as a given copper conductor has an effective cross-section in the ratio of 100 to 60; that is to say, the effective sectional area of an aluminium conductor is 66·66 per cent. greater than that of the equivalent copper conductor, and the diameter is about 29 per cent. greater. The specific gravity of cast aluminium is about 2·56, but when drawn into wire this is increased to 2·71. As the specific gravity of copper wire is about 8·95, the relative weight of a given volume of each metal is in the ratio of 8·95 to 2·71 or 3·3 to 1·0. In other words, a copper wire of any given size and length will weigh 3·3 times as much as an aluminium wire of the same size and length. Aluminium, therefore, having a conductivity of 60 per cent. of that of copper, will have a sectional area 1·666 times as great as a copper conductor of the same resistance and length, and the ratio of the weights will be 3·3 to 1·666 = 1·98 to 1. That is, a copper conductor of any given resistance and length will weigh approximately twice as much as an aluminium conductor of the same resistance and length. These ratios are summarised in Table II.

TABLE II.—*Comparative Ratios of Copper and Aluminium.*

	Copper.	Aluminium.
Conductivity for equal section	1	0·6
Section for equal conductivity	1	1·666
Diameter for equal conductivity ...	1	1·29
Weight for equal bulk	3·3	1
Weight for equal conductivity	2·0	1

If we assume for the sake of argument that the price of copper wire at cable works is 7¾d. per pound (equivalent to electrolytic wire bars at £60 a ton c.i.f.), and aluminium wire 10d. per pound, then the net selling prices of bitumen insulated cables are about as given in Table III.

Table IV. gives particulars (prepared for this paper by Messrs. Johnson and Phillips) of copper and aluminium cables. The prices include for metals at usual market rates, November, 1912, and for freight to the North of England. The three cores are cabled up, jute-wormed, paper-insulated, and lead-covered; the lead is served with compounded jute, and single-wire armoured, and finally the cable is served with compounded jute. It will be noted that although the weights of the armoured aluminium cables are about 17 per cent. greater than the copper cables, the prices of the aluminium cables are 5 per cent. less for round conductors and about 8 per cent. less for sector-shaped conductors.

TABLE III.—*Prices of Bitumen Insulated Cables.*

Copper.		Aluminium.	
Section, sq. in.	Price per mile.	Corresponding size of aluminium.	Price per mile.
	£		£
0·025	51	7/·087	44
0·050	87	19/·074	70
0·150	200	37/·092	155
0·250	287	61/·093	240
0·300	315	61/·102	255
0·400	440	91/·096	350
0·500	550	91/·108	440
0·700	740	127/·108	640
0·750	780	127/·112	650
1·000	1,110	127/·129	900

TABLE IV.—*Particulars of Three-core Medium-tension Paper-insulated Shaft Cables.*

Shape of conductor.	Conductors.	Diameter, inches.	At per mile (approximate).		
			Net weight.	Gross weight.	Price £
Round	0·15 sq. in. Cu.	2·32	375	471	1,053
Round	0·25 sq. in. Al.	2·72	440	560	1,003
Sector	0·15 sq. in. Cu.	2·11	328	424	993
Sector	0·25 sq. in. Al.	2·50	388	508	918

Fig. 2, which has been calculated by the British Aluminium Company, is of special interest, because it shows at a glance the saving on the net costs of bitumen and of paper-lead low-tension aluminium cables. The costs are arrived at on a basis of copper wire at 10½d. per pound and aluminium wire at 11½d. per pound. The cables are in accordance with the specifications of the Engineering Standards Committee.

It has been suggested that aluminium is an unsuitable metal to use for shaft cables because during erection the metal may be stressed unduly. Calculations, however, show that on account of its lightness, the factor of safety of aluminium due to its own weight is only slightly less than that of steel. From Table V. it can be seen that hard-drawn aluminium

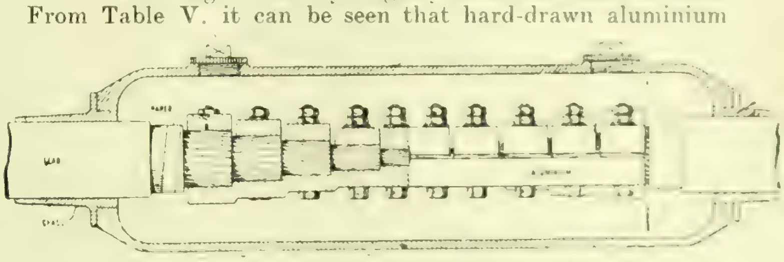


FIG. 4.—JOINT FOR 1·66 SQ. IN. ALUMINIUM CABLE.

wire is a much better metal from the point of view of supporting its own weight than either copper or steel. If annealed it is only slightly below steel and about twice as good as copper.

It really is surprising what prejudice one encounters when discussing the use of aluminium cables. For example, the writer has heard it stated that aluminium wire could not be purchased in large gauges and in long enough lengths for cable manufacture. On enquiry, he found that aluminium has for years been made as a regular thing up to No. 12 S.W.G., and in continuous lengths up to two miles. On another occasion an electrical engineer stated to the writer that there was no market for scrap aluminium, whereas scrap copper can be sold readily. The facts are that there is a good market for scrap aluminium, the makers themselves being amongst the regular purchasers. It is, however, true that the

margin between the new and scrap metals is slightly greater than with copper.

TABLE V.—*Tensile Strength and Weight Ratio of Copper, Aluminium, and Steel Strands.*

	Copper.		Aluminium.		Steel.	
	Hard drawn.	An-nealed.	Hard drawn.	An-nealed.	Hard drawn.	An-nealed.
Tensile strength, lbs. per sq. in.	60,000	23,000	30,000	16,000	70,000	50,000
Specific gravity	8·9	8·9	2·7	2·7	7·8	7·8
Weight per foot per sq. in. ..	3·87	3·87	1·175	1·175	3·39	3·39
Maximum length in feet of strand which can be supported	15,500	5,950	25,000	13,600	20,700	14,750

Jointing. —One feature which differentiates aluminium from copper is that it is not so easy to joint, but it must be remembered that a shaft cable is really a main feeder and is only tapped at the end. If it were a distributor, it would be a different matter, for it might then be tapped anywhere along its length, and the tappings could only be made on to the outside layer of wires. Various aluminium solders are available, but they are not easy to use, and are not to be recommended. Electric welding makes the best job, but it cannot be conveniently applied, and the great heat is liable to injure the insulation. It is usual to depend on a mechanical joint which will give sufficient pressure to break

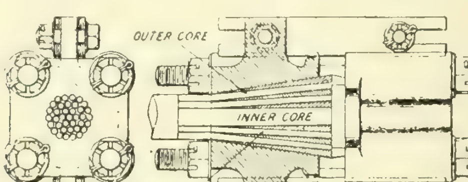


FIG. 5.—MECHANICAL CORE-TYPE JOINT FOR 1·4 SQ. IN. CABLE.

down the layer of non-conducting oxide on the surface of the aluminium. Separate connections are made on to each layer of wires, as shown in Fig. 3, which is a joint between an aluminium cable and a copper cable. Mr. S. L. Pearce has informed the writer that with the joint shown in Fig. 4 he obtained equal conductivity with copper, even though there were as many as six such mechanical joints in series on one feeder. The junction box is of cast iron, 20in. long and 6in. square, and is used for connecting two 1·66 sq. in. feeders.

In all cables, and especially those insulated with paper, it is important that means should be taken to prevent moisture working along the interstices of the strands. In copper cables this is often done by sweating all the wires together at the end so as to make it solid. Aluminium wires can be sweated in the same way, but it is a much longer process, and therefore it is usual to depend on filling the junction box with compound to keep out moisture. This filling with compound also has an advantage in locking the mechanical connections; for there exists a fair amount of evidence that when alternating current passes across a mechanical joint the bolts tend to slacken. It should be mentioned that the strands of aluminium cables can be treated with waterproof compound so as to fill the interstices, just as is done with solid-filled bitumen cables.

(*To be continued.*)

Water-diviners on Trial. —Interest is being aroused in the forthcoming systematic investigation of the claims of the water-diviner. From time immemorial persons have professed ability to discover minerals or water by the use of a forked hazel twig or dowsing rod, and it is undoubtedly a fact that prospectors, acting under their advice, have in many instances found water at the spots indicated. The trials in question, to be conducted on April 3rd, will be under the observation of Prof. Henry Adams, M.Inst.C.E., Messrs. Samuel Rideal, J.P., D.Sc., Herbert Lapworth, D.Sc., Searles Wood, F.R.I.B.A., W. Whitaker, B.A., F.R.S.

AIDS TO SCIENTIFIC FOUNDRY MANAGEMENT.*

BY W. M. CORSE.

ONE of the first steps in the scientific management of a plant is to plan a proper organisation. This gives everyone a base on which to start and clarifies the atmosphere of petty jealousies and misunderstandings. With this organisation chart before us we can follow out the various departments and finally perfect an harmonious working people. My own plan is to start a system of factory records in order that the management may have written information of the happenings in the shop at the present time and a record for the future. These may be daily, weekly, or monthly reports and should serve to furnish information that will give a mental picture of affairs in a concise manner. These records should be immediate, adequate, and permanent. I shall attempt to describe some of the records I have used with success in a brass factory. I do not say that these are all that are needed, or that better cannot be found for special cases, but simply that those mentioned will aid the manager to see more clearly the conditions with which he has to contend daily.

The first and most difficult report to keep accurately is that of the metal melted and of the output. We may call it the metal report or practice sheet. To secure positive results it is wise to have a separate room in which to store the daily supply of metal for the various mixtures and the shop scrap from each alloy produced. These should be kept in separate bins or boxes, properly marked with the alloy number, so that errors in weighing can be minimised. As many alloys look similar in outward appearance, great care should be exercised first in taking the castings from the foundry to the cleaning room, and next in taking the gates and risers and defective castings from the cleaning room and inspection departments. In this case, as in all movements of goods in process, the arrangement of the various departments should be such that the metal moves in a direction that does not cross or back track other material. The tagging of alloys that cannot be readily picked out by their appearance will aid materially in keeping this record accurate. The progressive jobbing foundry will frequently have 25 standard alloys, as well as a large number of special mixtures.

Let us follow the process of the metal and note the steps in that process. First, the storekeeper weighs out the bulk metals to the foundry metal room, receiving in return a signed requisition from the weighmaster. This requisition serves as a check on the store records and aids the purchasing department in balancing the materials account with the accounting department at the end of the month. Second, the weighmaster weighs out the various amounts of new metals and shop scrap for the mixtures ordered by the furnace department, using the daily working formulæ given to him by the metallurgist in charge of the laboratory. Before delivering the mixtures to the furnace department, the weighmaster should record on a special ruled sheet the alloy number, furnace number, and the weights of the constituent metals. At the end of the day this sheet goes to the metallurgist to be checked and from there to the cost office for compilation. The totals of these daily sheets for a week give the amount of each alloy charged to the furnace department, and when credited with the amount remaining at the end of the week, shows the metal melted for that period. They show not only the amount of the various constituents used in each alloy, but also the total of each metal used for the week. They further show exactly what each furnace is producing. This information can be used for determining the consumption of metal, and gives the purchasing department an accurate figure on which to base future purchases for the maintenance of sufficient stock for the orders on hand. It would hardly seem necessary to draw attention to this record, but I have often been surprised to find that no such information is available in many large foundries.

We now have figures on our weekly summary sheet which may be said to constitute the debit side of the account. The credit side of the account consists of the output of the foundry, divided into ingot metal, good castings, bad

* Paper read at the meeting of the Pittsburg Foundrymen's Association, March 10th, 1913.

castings, gates, risers, and recovered metal. They are weighed by the inspection department, the first three coming from the inspection department itself, the fourth from the cleaning room, and the fifth from the recovery department. They are separated first by day's work, then by alloys. Subtracting the output of each alloy from the metal charged to the furnace department, will give the gross loss of each mixture and the difference of the totals the gross loss of the foundry for the work.

The net loss is figured at the end of any period by assaying recovered metal too fine to be returned direct to the foundry, from the metal recovery department, figuring the weight of metal recovered and subtracting it from the gross loss. For cost purposes the net loss by weight cannot be used because the recovered metal cannot be sold for its full value to the smelter. We therefore estimate the value of the metal melted for the period in question, divide it into the amount received from the smelter for the recovered metal, thus arriving at the percentage of the recovered metal. This is subtracted from the gross percentage loss to be added to the formula cost of the alloy. This is not strictly accurate in that the gross percentage loss by weight may not represent the formula cost of the new metal, but as the more volatile metals are usually the cheaper, the error is on the safe side.

Let us take an example: The new metal may consist of 85 parts of copper, 5 parts tin, 5 parts lead, and 5 parts zinc. This would cost on the basis of 50-cent tin, $4\frac{1}{2}$-cent lead, 15-cent copper, and 7-cent zinc, about 15·82 cents a pound. If we are making ingot metal, we would add the approximate net loss of 3 per cent., determined as outlined above, or 0·47 cent to 15·82 cents, giving us 16·29 cents as the cost of the metals constituting the alloy. The fact that such a figure does not give the cost of the alloy in the castings is frequently overlooked in cost accounting. Let us see why these figures cannot be used in estimating cost of castings. If we melt 100lbs. of metal we may assume in ordinary brass foundry practice that we will net about 45lbs. of good castings. It is apparent that 100lbs. of metal costs in the formula 15·82 cents per pound, and that we lose 3lbs. valued at 0·47 cents. Therefore, 45lbs. of good castings would cost $45 \times 15{\cdot}82$ cents or $7.13. Figuring the loss on the value of the good castings we get $0{\cdot}47 \div 7{\cdot}13$, or 6·6 per cent. The metal in the castings, therefore, costs $15{\cdot}82 + (6{\cdot}6$ per cent. of $15{\cdot}82)$, or $15{\cdot}82 + 1{\cdot}04 = 16{\cdot}86$ cents. per pound.

An easy way to determine the amount to be added for loss is to divide 100 by the percentage of good castings produced, in this case 45 per cent., giving a factor of 2·2. Multiplying the net loss of 3 per cent. by the factor 2·2 we get 6·6 per cent., which is the same as we determined by the other method. We now have found by the use of the metal report or metal practice sheet, a means of checking the store records, the amount of metal melted, the output and the factors to be used in figuring the value of the metal for cost purposes. You will agree that these are all essential figures and also that we have determined one of the three elements of any cost, namely, material. The other two elements, labour and expenses, are determined by any of the accepted methods of cost accounting.

The second record of importance is the daily casting report. The first essential for this report is to have every day's work kept absolutely separate in all departments handling the castings, except the shipping room. There are many advantages in keeping the day's work separate, which pay for the extra labour involved. As soon as the castings are shaken out, they are checked for count and customer's name by the foundry clerk and sent to the cleaning room. This record is made in duplicate in the left-hand columns of the report, and a copy goes to the production clerk, who records the number of the pieces made on the shop order, which is a copy of the customer's original order. This in turn enables the production department to keep in close touch with the orders in process.

As the castings come from the cleaning room, they are examined in the inspection department, and the weight and count of good and bad pieces noted. The good castings pass directly to the shipping department; while the defective pieces are sorted by pattern number and by moulders' numbers, on a bench set apart for that purpose. When the day's work is all inspected, the foundry superintendent and factory engineer go over each lot of defectives and note the causes of defect. This serves to furnish information for the immediate correction of excessive losses. We all know that one of the big leaks in any foundry is the amount of bad castings, so that the relatively small amount of time spent in their examination will surely lead to large savings. It is surprising how frequently this examination is casual, instead of systematic, and it generally needs a cost record to emphasize the amount of the loss through defective castings before much attention is paid to this feature. A bonus paid to the foremen when the percentage of defectives drops below a stated amount, will often stimulate interest in this matter.

The inspection department records the number and weight of the good and bad pieces opposite the count noted by the foundry clerk on the daily casting report and the percentage of defectives, by pieces, is calculated. This report is arranged by moulders' numbers so that it will show the foundry superintendent and factory engineer the quality of work being turned out by each moulder. A compilation of the daily reports for the week will show the percentage of loss by each moulder, and the weight of castings produced. The latter when divided by the number of working hours will show the number of pounds produced per moulder per day for the week. This serves as an excellent check on each moulder's efficiency.

Another compilation will show the total castings produced per alloy by weight and pieces and also the total weight and pieces for the week. This is the source of part of the information regarding output which was mentioned under the metal report in the first part of the paper. From the total weight and pieces is figured the average weight of the castings produced and the total defective loss in percentage by weight and pieces. This gives a good general idea of the efficiency of the foundry department when taken in connection with average number of pounds produced per moulder per day.

You will see that a careful study of the reports as described will give a good general view of the conditions in the foundry. If one wishes, the results may be plotted on a graphic chart which will show these conditions at a glance more effectively than a report consisting of the figures only. When a job is of sufficient length to make it advisable, the record of the defectives may be kept on cards arranged by pattern numbers. The average of a period points out the excessive defects and indicates the patterns to be improved immediately, in order to gain maximum benefits.

The third set of records that I might mention are the individual cards showing the exact time spent on each job. On these cards are entered the weight and count taken from the daily casting reports, thus giving a complete record of the job to be used as a basis for figuring its cost. The various items of expense chargeable to each job are taken from the expense analysis of the month preceding. This expense analysis is made up from the pay roll, which has been subdivided by job or standing plant order numbers, and the various items of expense are taken from the store room requisitions and the voucher register in the accounting department.

To summarise, we have the sources of information for the three items of cost, viz.: Material, labour, and expense. (1) The metal report which gives the cost of material. (2) The individual cost cards which give the labour on each job. (3) The expenses analysis which gives the items of expense chargeable to each hour of productive labour on each pound of castings produced, depending on which method is followed in figuring the expense in the department in question.

In order to manage any business scientifically the basic facts which underlie it must be known. As a step in this direction, the reports mentioned above will serve to give fairly complete information. Many others can be added to give specific information, such as figuring piece work rates and standard time and bonus rates, but these should, in my opinion, follow those first mentioned. I have tried to outline the use to be made of a few principal reports with a view of stimulating interest in securing accurate information. It is only by this means, I believe, that the so-called scientific management can be introduced in a foundry. After a year or two the more complex methods of pay and performance can be added, but I think the mistake may be made of trying to introduce too much at first, thus causing confusion and distrust on the part of all who should reap the most benefit from a perfected system of cost and efficiency.

THE BRICK ARCH AS A FACTOR IN LOCOMOTIVE BOILER PERFORMANCE.

IN the tests, series "B," made by Dr. W. F. M. Goss on locomotive boilers equipped with Jacobs-Shupert and radial stay types of fireboxes, respectively, and recorded on another page of this issue, there was given opportunity for securing data on the value of a brick arch in a locomotive firebox. Certain of the tests on both boilers were run with the arch, and others were run without and under both conditions, both

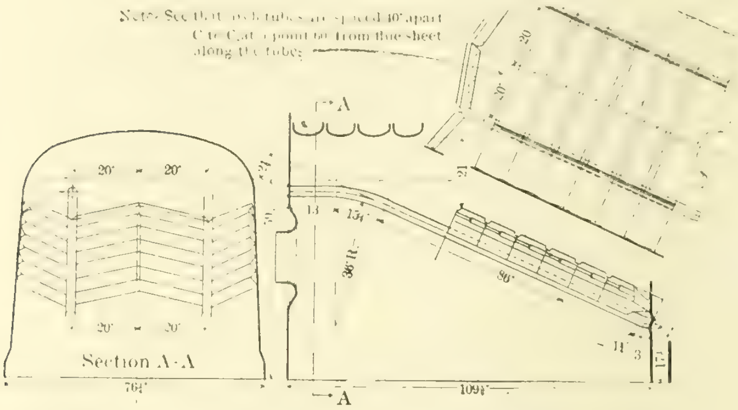


FIG. 1. ARRANGEMENT OF ARCH AS APPLIED TO JACOBS-SHUPERT FIREBOX.

the Scalp-Level and the Dundon varieties of coal were used; the former being high and the latter low in volatile content. The arches used in these tests were substantially the same for both boilers, but the curvature of the firebox sections of the Jacobs-Shupert boiler made necessary some slight differences in design.

The arch as installed in the Jacobs-Shupert boiler is shown by Fig. 1, and as installed in the radial-stay boiler by Fig. 2. The evaporative efficiency of the boilers with and without the arch is well shown by Fig. 3. In this figure the points shown as triangles represent tests (Nos. 201 to 302, inclusive) without the arch. Nine of these tests were run with Scalp-Level coal, five on the Jacobs-Shupert boiler and four on the radial-stay boiler. The long dotted line drawn through this group of points may be accepted as representing the performance of both boilers without the arch fired with Scalp-Level coal. Similarly, the points located by squares represent results from both boilers with the arch. Six of these points represent tests with Scalp-Level coal, and the long full line may be accepted as fairly representing them.

The addition of the arch raised the performance of these boilers from that represented by the dotted line to that represented by the full line, an increase of 0·6 of a pound in the amount of water evaporated per pound of coal. For example, assuming the boilers to have been fired with 6,500lbs. of Scalp-Level coal per hour, they will evaporate 7·35lbs. of water per pound of coal without the arch and 7·95lbs. of water per pound of coal with the arch, a gain of 8 per cent. Comparisons involving lower rates of combustion lead to smaller gains when these are expressed as a percentage of the evaporative efficiency. In the light of these experiments, it is fair to say that the addition of an arch in the firebox of locomotives using Scalp-Level coal results in increasing the efficiency from 5 to 8 per cent.

The points representing tests with Dundon coal are three in number. One representing the Jacobs-Shupert boiler and one the radial-stay boiler without the arch are shown on Fig. 3 as triangles enclosed in circles, and one representing the Jacobs-Shupert boiler with the arch as a square enclosed in a circle. A short dotted line is drawn through the two points representing the two tests without the arch, and a short full line through the one point representing the test with the arch. The difference in the location of these lines measures the effect produced by the arch. It represents an evaporation of 1lb. of water. Thus, when 6,500lbs. of Dundon coal are fired per hour, the boilers without the arch will evaporate 7·7lbs. of water per pound of coal, and with the arch they will evaporate 8·7lbs. of water per pound of coal. This means that with Dundon coal the addition of the arch resulted in increasing the evaporative efficiency to the amount of 12 per cent. The results of the heat analysis for two tests at substantially the same rate of power, one with the arch and one without it, are presented as Fig. 4.

The difference in the effect produced by the arch in connection with the two grades of coal is, doubtless, to be found in differences in the manner in which the coal burns. The Scalp-Level coal has only half the volatile matter of the Dundon coal. The benefits to be derived from the presence of an arch —the longer flame way, the better mixing of gases, and the conserving of high furnace temperature—are all matters which affect its combustion favourably, but the long-flame Dundon coal being in greater need of these advantages, naturally profited most by the presence of the arch.

ECONOMIES IN THE USE OF ELECTRIC POWER.

IN a paper on this subject recently presented before the Birmingham section of the Institution of Electrical Engineers, Mr. W. E. Milns emphasized certain important considerations which were often neglected by engineers and others responsible for installing and developing the electric drive. The author was of opinion that the commercial canvasser who lacked any technical knowledge, but possessed those qualities of salesmanship which enabled him to get motors into consumers' premises, was a dangerous person to employ. Such a canvasser was not able to discriminate between those jobs which were suitable and those which were ill adapted for the electric drive, and he could not recognise the importance of keeping certain power installations off the mains. The author could not too strongly emphasize the importance of technical advice in arranging an electric drive. Electric motors were too often installed on the advice of commercial assistants, wiring contractors, mechanical engineers, or others possessing little or no electrical knowledge. The results were often lamentable, a shunt motor being recommended in all circumstances and for all purposes.

Considering the many types of electric motors and the great variety of control gear, it was a pity that the shunt motor with an ordinary starting switch was apparently used on every possible occasion. A commercial engineer with technical knowledge should find no difficulty in inducing a reasonable-minded consumer to obtain, at slightly greater expense, the type of motor or control gear which would give the maximum efficiency and the greatest convenience, and not only would cover his requirements, but would also give many advantages not found in the usual installation. Technical knowledge was also essential in handling alternating-current work. The comparatively few speeds which might be obtained with alternating-current motors of a given frequency called for both electric and mechanical knowledge in cases where any form of gearing was used or speed variation required.

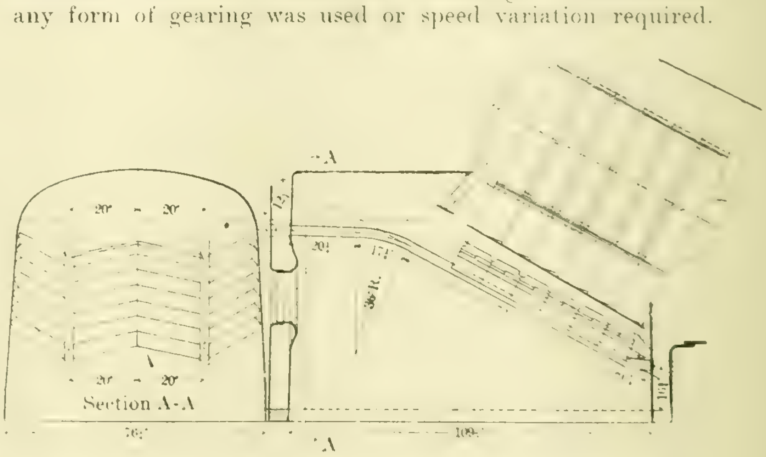


FIG. 2.—ARRANGEMENT OF ARCH AS APPLIED TO RADIAL-STAY FIREBOX.

Unfortunately, in many cases the engineers who handled power installations displayed a lack of knowledge of the various forms of electrical apparatus which otherwise might be brought to the notice of manufacturers. The blame for the majority of unsuccessful installations of electric power should, however, rest on mechanical engineers rather than on electri-

cal engineers. Those responsible for the electrical equipment should be able to criticise the arrangement of the drive suggested by mechanical engineers.

The heaviest item in a manufacturer's expenses was, he remarked, usually the wages bill. The power arrangements should therefore be designed to affect the wages account rather than the power account, *i.e.*, the designer of the arrangements for distributing power in a factory should not allow his engi-

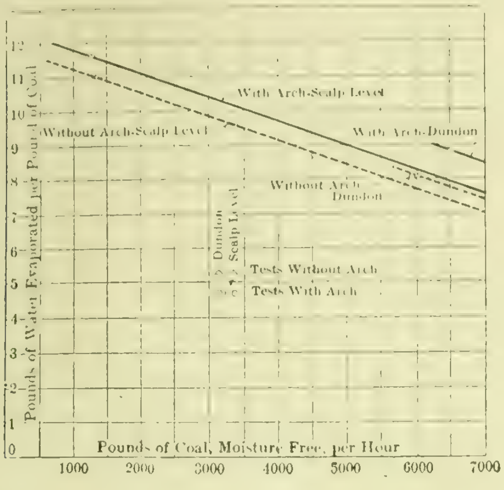


FIG. 3.—EFFECT OF BRICK ARCH ON FIREBOX EFFICIENCY (See page 348).

neering views to override the commercial considerations of the case. A well-thought-out power scheme would often increase the output for the same wages bill (this was equivalent to a reduction in the wages bill); and it would also cut down the manufacturers' expenses by saving material, reducing the floor space occupied, and minimising wear and tear and other maintenance charges. To design a successful power scheme for a works, the engineer must have some knowledge of the trade or manufacture carried on in those works. The works manager or works engineer was a most valuable ally, and much information could often be obtained from him. The author did not advocate that the most efficient mechanical arrangements should be installed regardless of cost. The subdividing of shafting and the individual driving of machines would occasionally reduce current consumption, but the capital cost of such arrangements could not always be justified. It was sometimes cheaper to consume a little more current and save capital outlay than to introduce expensive mechanical alterations. Each case must be decided on its merits. Considering the arrangement of plant, the following typical example showed what economies might be effected by an efficient arrangement of drives: A test on the premises of a Birmingham firm showed that 70 per cent. of the total energy was absorbed in shafting and transmission losses. A sensible arrangement of motors would reduce these losses to 30 per cent. It would pay to rearrange the works, and to take electricity at 2d. per unit with the reduced transmission losses, rather than to continue to use the existing drive.

As previously indicated, too much importance was attached to the cost of power, and it was also difficult to get a manufacturer to realise the many considerations which were put forward when comparing estimates for the cost of driving. We were all familiar with the gas engineer's somewhat crude method of comparison between gas and electric driving. The power user was usually told that, say, a 10 h.p. gas engine took 20 cub. ft. of gas per horse-power hour. On a 50-hours per week basis this worked out at 10,000 cub. ft. of gas, which, if charged at 1s. 6d. per 1,000 cub. ft., equalled 15s. On the other hand, the customer was told that a 10 h.p. motor consumed approximately one unit per horse-power hour, which was equivalent to 500 units per week. Taking current at 1d. per unit, he was thus shown that the electric motor would cost 41s. 8d., against 15s. for a gas engine.

When a manufacturer asked for the cost of electricity per horse-power hour, and said that such a figure would enable him with his own knowledge of his work to estimate his costs, it was wise to ignore the question. The author's experience was that the manufacturer had a very vague idea of horse-power, was ignorant of both his maximum and average load, and could not estimate his horse-power hours. A better method of estimating the cost of driving was based on figures actually obtained from existing manufacturers' installations. For the benefit of power users and engineers engaged in developing power loads, the author gave some figures obtained from the analysis of power costs in various trades. The figures given showed the number of units used per annum per horse-power installed, the figure being the average of a number of manufacturers in the same class of business. The installed horse power was such as was usually found in a factory where a little margin was allowed for development and extra load.

Electrical Energy used in Various Trades.

Trade.	No. of units per annum per h.p. installed.	Trade.	No. of units per annum per h.p. installed.
Bakers and confectioners ..	427	Leatherworkers	730
Bedstead manufacturers	613	Metal-workers ...	672
Boot manufacturers	591	Opticians	354
Brassfounders	927	Paper-box manufacturers	362
Brewers	689	Paper manufacturers ..	67
Brush manufacturers	454	Pen manufacturers	378
Builders	189	Photographic purposes	940
Butchers	278	Polishers	744
Button manufacturers......	570	Printers	569
Chemists (manufacturing) ..	1,699	Printers (newspapers)	833
Organ blowing	246	Provision merchants	408
Clothiers	938	Public offices (fans)	2,766
Cold storage	3,217	Public offices (lifts)	352
Corn merchants	267	Refiners	515
Die-sinkers	188	Rolling mills..............	486
Electroplaters	546	Surgical and dental purposes	353
Engineers (cycle)	987	Stampers and piercers	592
Engineers (general)	917	Upholsterers	167
Glass manufacturers	470	Vacuum machine companies (manufacturers) ..	371
Gunmakers	667	Varnish manufacturers	382
Hairdressers	178	Woodworkers	453
Ironfounders	781	Wireworkers	1,091
Jewel-case makers	893	Whip manufacturers	95
Jewellers	775		
Lamp manufacturers	1,331		
Laundries	421		

In addition to the above figures, it was also an advantage to give, where such could be obtained, actual comparisons of

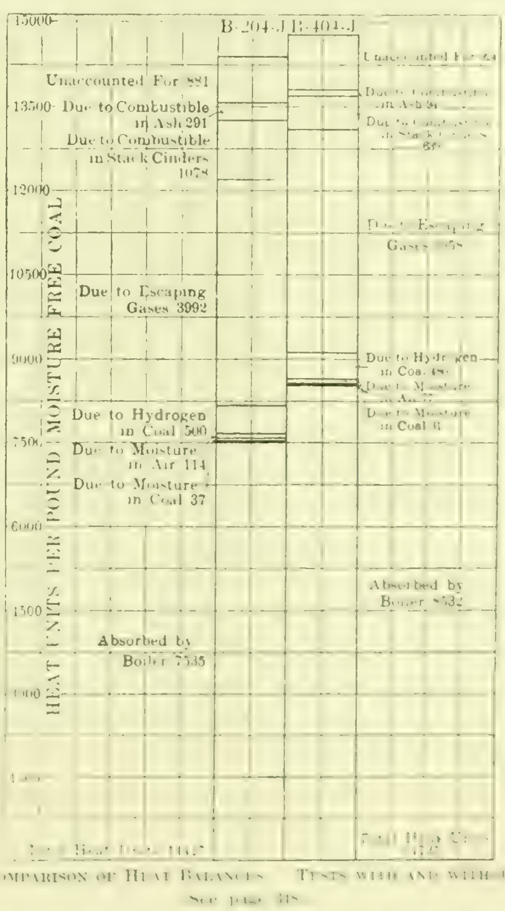


FIG. 4.—COMPARISON OF HEAT BALANCES: TESTS WITH AND WITHOUT ARCH. (See page 348).

the cost of gas, steam, and electric driving on the same work. Those familiar with power work no doubt had got many such

comparisons, examples of which were given below. These figures were obtained from manufacturers who previously used steam power and afterwards electricity, the work done in no case being less with electric driving than in the case of steam driving.

Horse-power installed.	Cost of driving by steam.	Cost of driving by electricity.
	£ s. d.	£ s. d.
1,387	6,000 0 0	4,000 0 0
200	1,680 0 0	1,476 0 0
80	750 0 0	504 0 0

The following figures were obtained from installations previously driven by gas plant operated with gas from town mains:—

Horse-power installed.	Cost of driving by town gas.	Cost of driving by electricity.
	£ s. d.	£ s. d.
25	130 0 0	104 0 0
5	33 9 0	23 9 7

The comparison below is for an installation previously driven by suction gas plant.

Horse-power installed.	Cost of driving by suction gas.	Cost of driving by electricity.
	£ s. d.	£ s. d.
40	156 0 0	144 6 10

The following interesting example was from a large pen factory, the owners of which had taken very careful tests on the cost of steam, town gas, suction gas, and electricity. The horse-power installed was 250. The cost of steam driving with "Corliss" compound condensing engines was £9. 10s. per horse-power per annum; with gas from the Corporation mains, at 1s. 5d. per 1,000 cub. ft., £7. 4s. 2d. per horse-power per annum; and with suction gas, £4. 17s. 3d. per horse-power per annum. The cost of electric driving with current at 1d. per unit came to £3. 13s. 9d. per horse-power per annum. The above typical examples took into account maintenance, wages, and repairs, while the example from the pen factory also took into account interest, depreciation, and all other charges. Such figures from actual results were powerful arguments for electric driving, and if permission could be given to use the name of the works from which the comparisons were obtained, the arguments carried conviction. Another method of comparison which would appeal to a manufacturer with an elementary knowledge of engineering was to obtain load curves for the steam engines by means of continuous recorders, or from electric motors by means of recording ammeters, and to submit such curves to a power user.

The manufacturer too often considered the uses of electricity from a power standpoint only. The many other uses which could be made for the supply were often of considerable convenience and value to him. A point could, for instance, be made of the better lighting of works. A last argument, which, unfortunately, was rarely taken into consideration, was that the conditions of labour and employment in electrically-equipped factories were usually far superior to those found in works utilising any other form of power. It had been considered necessary for the well-being of labour to enforce certain laws governing the lighting, ventilation, heating, and cleanliness of workshops and factories. It was safe to say that if electric power were universally used, and if no steam or gas were found in factories, these laws would rarely have been necessary. Practically in no case was steam or gas called in to improve the lighting, cleanliness, or ventilation of works. The introduction of electric power invariably gave better working conditions, and although these arguments might be somewhat advanced, there was no doubt they should be taken into consideration when considering the equipment of works and factories.

FIRECLAY FOR FOUNDRY USE.

BY E. H. OEHLER.

FIRECLAY is a highly refractory, earthy material, plastic when wet, and capable of being moulded into almost any desired shape. It is composed of particles of various minerals in different stages of decay, there being present oxides, carbonates, hydroxides, silicates, &c. The number of different minerals occurring may be quite large, but for general purposes clay may be considered as a combination of quartz, feldspar, and kaolinite, or some similar hydrous aluminium silicate. The latter is denoted clay substance, or clay base, and very largely contributes plasticity.

The ordinary chemical or ultimate analysis is one of the first essentials in selecting fireclay. A good fireclay for foundry use should approximate the following analysis:—

	Per cent.
$Si\ O_2$	55·00
$Al_2\ O_3$	29·00
$Fe_2\ O_3$	1·50
$Ca\ O$	0·50
$Mg\ O$	0·40
$Ti\ O_2$	1·60
Alkalis	1·50
Loss on ignition	10·50

Any very great increase in any of these constituents will cause a lowering in the melting point of the clay. Steel is cast at a temperature of about 2,900° Fah., and in order to withstand this heat, the fireclay should not fuse below 3,200° Fah.

The rational analysis of clay is also very valuable in judging its properties. This analysis is not undertaken as a rule, but its use should be more general. The following method gives very good results, and properly finds a place here. The object of the rational analysis is to determine, in a general way, the constitution of the clay. It shows the ratio of quartz, feldspar, and clay substance (kaolinite) existing in the sample.

Two grains of clay are digested with 20 cc. of concentrated sulphuric acid on a hot plate. The solution is cooled, diluted with water, filtered, and washed with hot water. The residue on the filter is washed into a 50 cc. beaker with about 15 cc. of 10 per cent. sodium hydroxide solution, and digested two or three hours with heat, then diluted with about 35 cc. of water, filtered, and washed. What remains on the filter is washed back into the beaker with about 25 cc. of hydrochloric acid (Sp. Gr. 1·1), and again digested, filtered, and washed. This last residue is ignited, and the loss represents kaolinite or clay substance. The successive treatments with acid and alkali have dissolved out the clay substance, leaving feldspar and quartz.

The residue, consisting of quartz and feldspar, is fused with sodium carbonate and the silica and alumina determined. Multiplying the percentage of alumina by 5·41 gives approximately the amount of feldspar present, and the quartz is found by difference.

Another method of arriving at the same result is to multiply the alumina in the residue by 3·51, which gives the amount of silica found in orthoclase feldspar. This silica subtracted from the total silica in the insoluble residue gives the percentage of quartz. The sum of the alumina, ferric oxide, alkalis, and 3·51 times the alumina, represents feldspar. Neither of these calculations gives absolutely correct results, but for the purpose of comparison the values are very interesting.

A simple method of calculating the clay base from the ultimate analysis is to consider all the alumina to be contained in the kaolinite, multiply it by 1,169 to find the amount of silica required, and add this product to the aluminium and combined water. Out of numerous samples, those running about 72 per cent. kaolinite, 6 per cent. feldspar, 22 per cent. quartz, show up very well in actual service.

Feldspar acts as a fluxing agent, and materially lowers the melting point. Kaolinite or clay base is composed of silica 46·4 per cent., alumina 39·7 per cent., water 13·9 per cent., and melts at 3,300° Fah. If kaolin is mixed with pure white sand in increasing proportions, it is found that the

melting point of the resultant mixture is lowered until the proportion, kaolin 10 per cent., and sand 90 per cent., is reached. With this mixture the melting point is about 3,000° Fah. Any further addition of sand raises the melting point. In this way it is seen that a high percentage of quartz quite appreciably lowers the melting point.

The refractory properties of any clay are most influenced by the bases in the following order: Iron oxide, magnesia, lime, soda, potassa, titanium oxide, and silica. The influence of the first five is most important, as comparatively small quantities affect the fusibility to a great extent. The fact that silica acts as a flux is interesting to foundrymen because it is the usual practice to add clay in mixing facing sand. The several characteristics of a good foundry clay are as follows:

It must have a low percentage of fluxing impurities, or, in other words, the percentage of iron, lime, magnesia, and alkalis must be low, about 3·50 per cent. The silica should run pretty close to 50 per cent., as any great increase over this lowers the melting point and also affects the plasticity.

It must have as much bonding power as possible, and this is largely due to the amount of clay substance or kaolinite present. The basis principle of good moulding is to keep the proportion of clay down, and the larger the percentage of clay substance, the less clay is required.

It should be finely ground, as the plasticity varies to a great extent with the size of the grain. The finer clay mixes more intimately with the sand. In this connection, it is well to note that facing sand should be well milled. Many scabby, dirty castings are the direct result of too much haste in mixing the sand, and in no way is caused by poor materials. It is very easy to test the fineness of the various clays by running them through sieves of several different degrees of mesh.

It is almost needless to state that fireclay for foundry use need not be of the highest grade obtainable. No. 1 fireclays such are are used for glass pots, which, undoubtedly, require the most refractory, are too expensive for foundry use, and as a matter of fact would not justify the added expense. The lower-grade clays, melting around 3,200° Fah. or 3,300° Fah., if properly used, will give just as good results. It sometimes happens that two clays of approximately the same chemical analysis show up very different in practice. One may give perfect satisfaction, while the other is the cause of much trouble. Very often the rational analysis will show wherein they differ, and for this reason its use should be more general. If it should fail, the only satisfactory test is to ascertain the actual melting points, which is usually a matter of great difficulty for the foundry chemist. The best method is to find a satisfactory brand and to stick to it.—"The Foundry."

PROGRESS OF BRITISH MILITARY AVIATION.

IN introducing the Army Estimates in the House of Commons on Wednesday of last week, Colonel Seeley furnished some interesting information relating to the progress that has been made in military aviation during the past year. When the previous year's estimates were introduced, he said, the War Office had only 17 aeroplanes, whereas now they had 101 machines capable of flying, and if there was no further delay in supply they would have 148 on May 31st. Experiments of a secret character had, he remarked, been conducted during the past year, with the result that they had now evolved a machine far superior to that in the possession of any nation in the world. They had had the best brains in England at work on it, and he wished to acknowledge the services rendered by the National Physical Laboratory, and especially the Committee under Prof. Glazebrook, who had done so much to produce this remarkable result. The Superintendent of the Royal Aircraft Factory, who was himself a member of the Committee, had carried out the work. The great problem of the aeroplane for the purpose of warfare, and especially for this country, was to have a machine that would not only fly at a great speed but also at a slow speed. The second was even more important than the first. The first was necessary because of the strong winds in this country, and in war speed was vital against a contrary wind, but slow speed was more essential for war in all countries. In any enclosed country to attempt to land with these exceptionally fast machines would mean certain death.

The problem to be solved therefore was to get a machine which could fly at a slow as well as at a great speed, and they had gone nearer to solving that problem than any other nation, and far nearer than they ever believed possible six months ago. They had now a machine which had flown at over 80 miles an hour which could also fly at 40 miles, a thing thought to be incredible six months ago. They had also a biplane which completed its tests on Monday. How slow it would fly they did not yet know, but in a series of four tests over a measured course this machine had averaged 91·4 miles per hour, flying backwards and forwards and with and against the wind. That meant that this machine attained at times a speed of 100 miles per hour. These were remarkable achievements, and reflected credit upon British inventive skill and genius, which, working quietly and silently, produced these remarkable results.

In regard to flying in violent wind, the Commandant of the Royal Flying School thought it essential to know in how violent a wind it was possible to fly. A brave young man whose machine could fly at 57 miles an hour took it out in a tremendous gale. The wind was so violent that the machine rose perfectly straight to a height of 300ft. In the teeth of the wind it took him 16 minutes to cover 400 yards, so that the wind must have been blowing at just under the speed of the machine. When they remembered that only a year ago people hesitated to go up in winds of 15 miles an hour it would be seen how great an advance had been made. In the converse case it took an airman an hour and a quarter to fly 21 miles with the wind dead ahead, but he did the return journey in 4 seconds under 12 minutes, or at a speed of about 115 miles per hour. In regard to monoplanes, the 101 machines of which he had spoken included some instructional machines, not of course fast, and others suitable for war, but involving an element of risk which they would take in times of peace. Since the formation of the Royal Flying Corps the machines had, he said, flown for 1,550 hours and covered 82,000 miles, or more than three times round the world. Unfortunately six lives had been lost, but on the other hand the Central Flying School had flown 670 hours and covered 36,000 miles without a single serious accident.

Regarding the time taken to manufacture an aeroplane, Colonel Seeley mentioned that arrangements could easily be made to manufacture a great number, far more than were possessed by any other country, in a very short time. The difficulty was with the engines. The weak point in England was that although they produced the best aeroplane and had many good engines they were produced in small numbers, and so far as they had yet been produced they were less efficient, if by efficiency they meant the speed attained to a given weight, as compared with foreign Powers. The Government had decided that the best way to meet this difficulty was to offer a prize, and not only a prize but the promise of a large purchase. He had arranged, in conjunction with the First Lord of the Admiralty, that the War Office and the Admiralty should together offer a prize for the best aeroplane engine. The details of the competition were being settled by a sub-committee of the Aero Committee. They proposed to give a prize of something in four figures, and to give a firm promise of the purchase of 50 or probably more of the engines of the successful competitor or of oné of the competitors. He was advised that that was the best way of stimulating the industry. He thought that there could be no doubt that they should find it possible to excel in the production of aeroplane engines in the same way as they excelled in the production of engines for motor cars and as they had undoubtedly excelled in the production of the aeroplane itself.

Institution of Engineers and Shipbuilders in Scotland.—At the sixth general meeting of this session of the Institution of Engineers and Shipbuilders in Scotland, held on the 18th inst at Glasgow, Mr. E Hall Brown, president, in the chair, the following were nominated for election later as office bearers for sessions 1913-1916: President, Dr. R. T. Moore; vice-presidents, Prof A L Mellanby, D.Sc., and Mr. T Blackwood Murray, B.Sc.; members of Council, Mr A. J Campbell, Mr. W M M Millan, Mr G A Mitchell, Engineer-Commander W M K Wisnom, R.N., and Mr H E Yarrow; associate member of Council, Mr Francis Henderson

SCHMIDT'S CONSTANT-PRESSURE INTERNAL-COMBUSTION ENGINE.

SOME important modifications in the design of internal-combustion engines of the constant pressure type are proposed in a patent recently granted to Dr. Wilhelm Schmidt, 2, Rolandstrasse, Cassel Wilhelmshöhe, Germany. In engines of this type, as at present constructed, the combustion air in the working cylinder is compressed to 30-35 times its initial pressure, and they work with a considerable degree of economy, but in comparison with the large dimensions of their cylinders and moving parts, develop only a comparatively small power. For this reason the manufacture of such engines of high power offers considerable difficulties, the possible cylinder dimensions in particular soon reaching a limit, so that high powers can only be attained by increasing the number of cylinders and, consequently, the cost per horse-power hour. The object of Dr. Schmidt is to render possible the use of constant-pressure combustion engines which, without sacrifice of economy, shall be smaller and lighter for the same power than engines of the type hitherto employed.

It has already been proposed to increase the initial pressure of the air to be compressed in the combustion cylinder by means of preliminary compression, and at the same time to reduce the compression ratio of the combustion air compressed in the combustion cylinder. These proposals, however, went too far, and the resulting engine was unsuccessful; thus a preliminary compression of 6-8 atmospheres was adopted and a compression ratio in the combustion cylinder varying from 1 : 15 to 1 : 6·5. The burnt gases were employed in a combustion product engine working after the manner of a hot-air engine, which on the one hand had to effect the preliminary compression of the combustion air, and on the other hand to deliver power to the shaft of the combustion engine, the engine as a whole being constructed as a compound engine in which both the temperature drop and the work were divided. This engine, however, was a complete failure, on account chiefly of the attempt made to compound it after the manner of a compound steam engine. The combustion product engine, which formed the low-pressure part of the compound engine, was not suitable for high powers, owing to its lack of economy, while the exhaust gases entered the low-pressure cylinder at a pressure of about 16 atmospheres and a temperature of 1,300°, the result being that not only the pipes connecting the cylinders but also the admission valve of the low-pressure cylinder, and the large low-pressure cylinder itself, were made red-hot, and had to be artificially cooled, thus causing great heat losses. Even in the combustion cylinder the losses were increased, because the exceptionally low expansion ratio, due to the low compression ratio, necessitated a very late cut-off (almost 50 per cent.) in the combustion cylinder, and this in turn involved large cooling losses and a high temperature of the gases throughout the whole of the piston stroke.

According to the present invention the compression of the combustion air compressed in the combustion cylinder is fixed at 12-24 times the initial pressure of 2-4 atmospheres. Preferably the ratio of compression and the ratio of expansion dependent thereon are so chosen that the energy in the exhaust gases is sufficient alone for driving the preliminary compression plant. The compression pressure, which, according to present practice, amounts to 30-35 atmospheres, is thus increased to 60 atmospheres or more, the reduction of the ratio of compression in the cylinder to about 12-24 times proceeding hand in hand with the increase of the initial pressure of the combustion air to be further compressed in the working cylinder. The increase of the initial pressure allows a larger weight of air to be introduced with smaller cylinders, a feature on which, apart from the quantity of fuel supplied, the output of a constant-pressure combustion engine essentially depends. For example, the increase of the initial pressure to about four atmospheres absolute, other things being equal, reduces the stroke-volume to a quarter of that hitherto usual. The reduction of the compression ratio is associated with a simultaneous decrease of the expansion ratio, or, in other words, with a reduced compression ratio, the cut-off takes place later, a moderate retardation of the cut-off as compared with what is usual in the ordinary constant-pressure engine being desirable. From a theoretical point of view, the reduction of the expansion ratio is a retrograde step compared with present practice, but the disadvantage involved is counterbalanced by other advantages. For example, taking the initial pressure of the combustion air as before at four atmospheres absolute, then for the same weight of air the cooling area of the cylinder walls under identical conditions amounts to only one half and the areas of the cover and the piston to only a quarter of the corresponding areas according to present practice. The cooling losses, which now amount to about 33 per cent. of the total heat, are thus reduced at least one half, while the amount of heat available in the cylinder for conversion into work is correspondingly increased.

With the increase of the combustion pressure, later cut-off, and considerably smaller dimensions of the cylinder is associated a more perfect combustion, that is to say, the high compression pressure leads to an increased concentration of the oxygen molecules, which makes the combustion more lively. The smaller dimensions of the cylinders, apart from running advantages, ensure a more uniform mixture of fuel and air. The later cut-off, with a given weight of fuel per cycle, affords a longer period for the combustion (with regard to the stroke), which offers a greater security for complete combustion, so that the objectionable after-burning during expansion is avoided. In addition to the thermal advantages set forth, the mechanical efficiency of the engine is also increased.

The mechanical efficiency of the constant-pressure engine as at present constructed is low in comparison with other engines, the ratio of the brake horse-power to the indicated horse-power being not more than about 75 per cent. This low efficiency is due on the one hand to the relatively large negative work of compression with an early cut-off, and on the other hand to the high maximum pressures acting on the pins, journals, and the like, in proportion to the power developed. The mechanical efficiency of the new engine is higher both because the negative work of compression is less and also because the maximum pressures are decreased in relation to the power. In some cases, if, in spite of the rise of temperature due to the preliminary compression and the reduced cooling losses, the low ratio of compression in the cylinder does not produce a sufficiently high temperature for ignition purposes, the combustion air may be heated artificially before admission to the working cylinder, so as to ensure the attainment of a reliable ignition temperature.

The object aimed at in many earlier proposals has been to reduce by cooling the initial temperature of the combustion air to be compressed in the working cylinder, in order to increase the weight of air that could be introduced at atmospheric pressure or at a superpressure of a few tenths of an atmosphere. With the low initial pressures of the old methods, this was of great importance, because an increase of temperature at such low initial pressures at once leads to a considerable decrease in power. With the process of working now proposed, however, an increase in temperature of the air before introduction into the working cylinder is of less importance. Nevertheless, in some cases, the combustion air may be cooled after the preliminary compression, in which case ignition must be artificially effected.

As a considerable expenditure of work is necessary for the preliminary compression of the combustion air, it is of great importance in connection with the new engine that the work of preliminary compression shall not fall on the combustion engine proper, or at anyrate that any such work shall be kept as low as possible. For this reason the exhaust gases of the combustion engine are utilised for the preliminary compression, these exhaust gases being fed to a combustion product engine (piston engine or turbine), which in turn drives the compressor (piston or turbo-compressor).

The exhaust gases of the proposed combustion engine have a much higher pressure and temperature than in engines proposed heretofore, and this fact enables them for the first time to be utilised profitably in a combustion product engine, even in the case of 2-stroke engines, in which the temperature of the exhaust gases, owing to the necessary excess of scavenging air is relatively decreased to a considerable extent. On

the other hand, the pressure and temperature of the exhaust gases are sufficiently low to render it possible to dispense with artificial cooling of the connecting pipes and the like. In most cases, by appropriate choice of the ratios of compression and expansion with usual combustion temperatures, the energy in the exhaust gases can be maintained at a level sufficiently high to drive the preliminary compression plant without additional assistance. The increase of the working capacity of the exhaust gases for the purpose of effecting the preliminary compression in an efficient manner is an important factor when considered in relation to the reduction of the ratio of compression in the working cylinder.

The preliminary compression plant may be coupled to the shaft of the combustion engine or be arranged independently, but it is of fundamental importance that all the external work of the cycle should be performed by the combustion cylinder.

It is to be particularly noted that the object of the new engine cannot be attained merely by increasing the initial pressure of the combustion air according to present practice without alteration of the ratio of compression or by merely reducing the ratio of compression without alteration of the initial pressure; the results sought, on the contrary, can only be attained by the simultaneous modification of both these features. The new method of working is suitable for all constant-pressure combustion engines, but is specially applicable to 2-stroke engines, since they are already provided with a compressor plant. The claims made by Dr. Schmidt are as follows: (1) A method of working constant-pressure combustion engines, according to which the ratio of compression of the combustion air compressed in the working cylinder is fixed at 12-24 times the initial pressure of 2-4 atmospheres, the object being to provide smaller and lighter engines in relation to the power developed, without sacrifice of economy. (2) A method of working constant-pressure combustion engines as claimed in claim (1), the ratio of compression and also the ratio of expansion being so chosen that the energy remaining in the exhaust gases is sufficient for driving the preliminary compression plant without additional assistance.

GAS PRODUCERS FOR SMALL HEATING FURNACES.

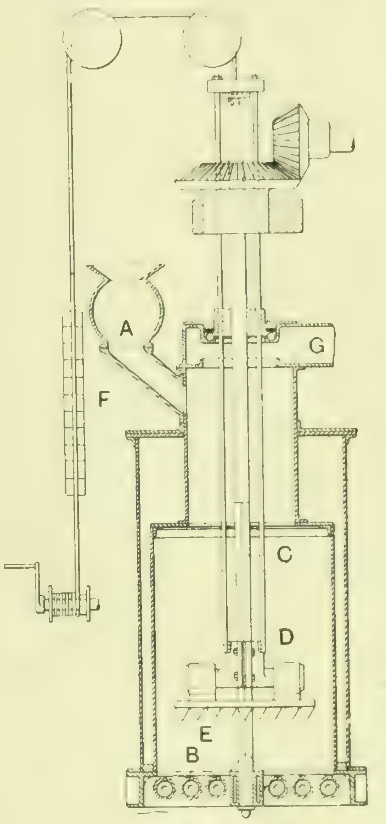
IN a paper read before the Cleveland Engineering Society Mr. C. D. Smith said that the increased cost of fuel oil had created a demand for some substitute for these fuels in small heating furnaces, and it was from producer gas that a solution of the problem was expected. In work of this character, little had been done with producer gas, and information along this line was difficult to get or was entirely lacking. For the supply of such furnaces it would be necessary to cool and clean the gas in order to avoid any clogging in the gas distributing system; the sensible heat of the gas as it left the producer would thus be lost, and any tar compounds that it contained and which were high in heat value would also be lost. With an average gas, thus cleaned and cooled and burned in a small heating furnace, temperatures of 1,700° to 1,800° Fah. were readily obtained, and in work requiring no higher temperature there was no reason for serious difficulty. A few installations had been made where temperature requirements were not high, such as for tempering, case-hardening, and heating soldering irons, and in these instances satisfactory results were reported. But in furnaces requiring higher temperatures, such as welding heats, small crucible furnaces, and heating material for bolt and rivet machines, the situation was uncertain; little was known, but the experimental stage of this development was well started.

So far as was known to the writer, there was but one plant in the United States where an attempt was being made to utilise producer gas for heating small crucible furnaces. Clean cold gas of about 120 B.Th.U. per cubic foot was used; the gas and air for combustion were preheated by means of the waste gases to about 600° Fah.; each furnace contained a crucible holding about 200lbs. of brass. Reports already received indicated that satisfactory results had been obtained; it was stated that the heat was ample for the purpose and that it was uniform. If continued tests confirmed the results as reported, the outlook was bright for the application of producer gas to this type of heating furnace.

If we measured the world's industrial development by the consumption of fuel, it was readily seen that we were progressing at a rapid rate, and as a period in the lifetime of a nation we had been using mineral fuel but a short time and we had learned little about it. The first fuel consumed was used in a crude way and most of the heat was lost. Although at the present time we were beginning to realise the desirability of more economic utilisation we were still very wasteful. In the efforts of the future to conserve the fuel resources and to utilise waste materials, the gas producer was destined to play an important part, and it was the firm belief that it was now entering upon a period of healthy and steady growth in its application to industrial pursuits.

CLIMIE'S GAS PRODUCER.

THE gas producer shown diagrammatically in the accompanying sectional view has been designed and patented by Mr. William Climie, 3, Mount Pleasant, Bo'ness, Linlithgowshire. It is composed of an inner and outer casing, the fuel being inserted within the inner casing and the water introduced into the space between the two casings. The fuel is charged into the producer by a shoot A fitted with a valve of the usual form. The grate is formed with toothed rollers B, which are continuously rotated so as to discharge the ashes and prevent the formation of clinker. The rollers are formed hollow so that water may be passed through them. The vertical tube or support C is fitted centrally within the casing and is continuously rotated by the gearing shown. Water is circulated through this tube in order to keep it cool. The lower portion of the tube C is of hexagonal form in section and a boss D formed with projecting arms is mounted on same so as to rotate with the tube C, but is capable of vertical movement thereon. A bar E having teeth on its under surface to form a rake is pivoted on the projecting arms of the boss D. As the rake is rotated by the tube C it is caused to rise through the fuel in a spiral manner.



CLIMIE'S GAS PRODUCER.

When the rake has reached the uppermost point of its vertical movement it continues to rotate on the top of the fuel, the level of which is falling by reason of the automatic discharge of the ashes by the rollers B. When the green fuel on the top of the coke or incandescent fuel has descended to the incandescent or coke zone a fresh supply of fuel is charged. A winch and rope are provided for the purpose of raising the rake in order to clear the tube C from the carbon that collects on it. In order that the position of the rake in the fuel chamber may be known an indicator F is fitted. The gas is led from the fuel chamber by the pipe G to a vessel of the usual construction where the tar and ammonia compounds are separated from it.

The Society of Engineers. An ordinary meeting of this society will be held on Monday, April 7th, at the Institution of Electrical Engineers, Victoria Embankment, W.C., when a paper will be read on "The Status of Engineers and Engineering, with Special Reference to Consulting Engineers," by William Ransom, A.M.Inst.C.E. This paper gained the second premium (the first not being awarded) in the Society's Prize Competition last year, and deals with questions affecting engineers in their relations with clients, assistants, contractors, and the general public. The author also discusses the training of engineering pupils, the question of registration, and a variety of other matters affecting the remuneration and professional status of engineers.

THE LONDON TRAFFIC PROBLEM.

In the course of a paper on this subject, read at a recent meeting of the Society of Engineers, Mr. W. Y. Lewis said it was his aim to endeavour to awaken Londoners to the seriousness of the present situation. The importance of the London traffic problem was hardly appreciated by those whom it most concerned, nor was it realised to what an extent the cost of living and other matters affecting the whole community were dependent upon transport. It was astonishing to learn, for instance, that the very large proportion of the 7,000,000 people in London who habitually used surface facilities would each spend on 'bus and tram fares an average of at least 20s. this year; while each would pass fully four 8-hour days in travelling less than 300 miles on these vehicles, to say nothing of three 8-hour days that he would spend in waiting for vehicles, and an equal time in watching for opportunities to cross the congested streets. They would probably make 1,500 million journeys this year, at a cost of £7,000,000, and yet there was no sign of concerted action except on the part of those who were financially concerned. For this reason especially the author was of opinion that the traffic facilities should be controlled by Government. The Press might do much to safeguard public interests, but it did not seem to realise that the object of the traffic trust formed on the American model was to place the London County Council in such a position that it would have no other remedy than to buy them out at an enhanced valuation. The traffic problem should, if possible, be lifted out of the arena of party politics, for cheap and effectively rapid transit was the life blood of trade and the breath of individual prosperity.

The author advocated the co-operation of Londoners for their own protection by means of a "London Transport Association," whose income might easily be £50,000 a year at a very low subscription per traveller. It should be founded on a universal representation. The author contended that the Londoner should awake to the fact that this matter had an important bearing upon his personal welfare, and should bestir himself to gain some impartial evidence on the subject. The formation of a "London Transport Association" was suggested for the purpose of studying the problems, educating the public, and using all possible means to secure cheap and effectively rapid transport. In this way the Press would receive valuable aid in putting before the public the best suggestions for the solution of London's many and differing transport problems—passenger and freight. At present the London County Council was baulked in every direction, and its tramway undertaking was excluded from the lucrative short-journey traffic which would be ensured by inter-connections through the central area.

The author then set out to investigate whether motor omnibuses adequately filled the needs of the central area and the connections with the immediate surroundings. He concluded that if they did so, which was not by any means the case, it was only at enormous cost to the traveller using them, although they "operated under conditions of unmatched freedom," conditions which could not be justified. The "door to door" speed possible with 'buses within the central area was on the average only 4 miles an hour. The average amount paid per passenger-mile ridden was at least 1d., and of every penny taken 58 per cent. was clear profit. In comparison with this, we found that on the Glasgow tramways the amount paid per ridden mile was under a halfpenny, while on the London County Council Tramways the amount paid per ridden mile was as low as ⅜d. The huge profit made by 'buses in the central area enabled the omnibus company to make big average profits, even if the surburban traffic was run at such rates as left in some cases little, if any, margin.

The analytical statements and facts founded on them given in the paper bore out the assertion that Londoners were being exorbitantly charged for the services rendered by the motor 'buses, and that the time "was ripe for them to take such action as would ensure reform." In the outskirts the trams served the public at least 36 per cent. less than the omnibuses, and the public consequently rode 55 per cent. further on the former than on the latter. Mr. Yorath Lewis concluded very naturally that his own system—the Adkins-Lewis System of Continuous Transport—was superior to motor omnibuses and tramways for the central area, and there could be no doubt that any form of continuous travelling would be much more effective than intermittent service. There was abundant evidence as to the safety of the system and its feasibility for public service, and if such a one could be established it would solve the problem of short haulage traffic across and within the central area of London.

WATER GAUGES AND LOW-WATER ALARMS.*

Water Gauges.—The water level in boilers may be ascertained by try cocks, wheel floats, or glass tube gauges. Try cocks soon get out of order, and reliance should not be placed on them alone. Wheel floats are still in use on egg-ended boilers, Rastrick and vertical cylindrical boilers; the wire or brass rod supporting the float is liable, however, to stick at the gland on the top of the boiler, and may give misleading indication of the water level. Glass tube gauges are now almost universally used, and as so much depends on them, care should be taken to provide good and reliable fittings, and to keep them in proper working order. Asbestos packed cocks are preferable, especially for high pressures, and both the water and steam passages should be as large as possible and kept clear of deposit. During the period 1904-08, three explosions occurred through passages becoming choked, and in one case four men were killed and two injured. The bottom fitting should be recessed to receive the glass, and care should be taken when putting in a glass to place it in this recess and screw up the bottom gland first. Packing of conical or hexagonal type is recommended to prevent the possibility of the packing being forced under the end of the glass tube. Broken glass should be renewed at once, and for this purpose a few spare tubes of the correct length should be always kept at hand. Water gauges should, wherever possible, be fitted directly to the boiler in such a position that the water level is visible with a depth of 4in. of water in the boiler above the furnace flue, and they should be sufficiently illuminated. To show the water level more clearly, enamelled reflectors, with lines marked on them, may be placed behind the glasses. Owing to the optical properties of glass and water, the dark horizontal lines appear shortened in the steam space and lengthened in the water space, while the diagonal lines appear horizontal through the water. With prismatic glasses the water appears black, and the steam space appears silvery, but with this type, if the water is dirty, or has an erosive action on the glass, in course of time a coating of dirt may collect on the inside of the glass, or the prismatic formation may be destroyed, and the glass will appear black when the water has actually left it.

Explosions from shortness of water should be reduced in number if the attendants, instead of opening only the drain taps of water gauges, tested them several times daily in the following manner to ensure that both the steam and water passages were perfectly clear:—

(1) Shut top tap.

(2) Open drain tap. A full blow of water shows that the water passage is perfectly clear.

(3) Shut bottom tap.

(4) Open top tap. A full blow of steam shows that the steam passage is also clear.

(5) Shut the drain tap.

(6) Open the bottom tap. The water should not be sluggish in returning to the glass.

These operations involve a certain amount of trouble, but they ensure that the glasses will indicate correctly, and also that the taps can be closed should a glass break. Gauges on water-tube boilers are often fitted with special rods and handles by which the taps can be operated either from the floor or platform at the gauge level. A tail pipe fitted to the drain tap and provided with a valve near the ground level is an exceedingly useful adjunct for frequent use, but it does not dispense with the regular routine testing mentioned above. Where there is a number of high-pressure boilers, the risk of

* Extract from "Memorandum on Steam Boilers," by William Buchan.

scalding can be greatly reduced if the attendant who tests the glasses wears a mask and gauntlets.

To prevent accidents from bursting glasses, they should be of good quality, and the fittings should be in line. When putting in a glass, it should be placed in the recess of the bottom fitting and the gland screwed up, and after it is secured in the top fitting in a similar way, it should just be possible to turn the glass by hand. The renewal of glasses every six months, instead of waiting until they break, is very good practice.

During 1908 19 accidents occurred in factories from bursting glasses, and in 10 cases the pressure was under 80lbs. Glasses are liable to be broken at low pressures; serious accidents have been noted at pressures of 50lbs., and in a recent case, a gauge glass protector was found on a boiler working at a pressure of 20lbs.; this had been fitted as the attendant had been injured through inadvertently breaking the glass with one of his firing irons. Some forms of gauge glass protectors are made of toughened glass, or of glass with embedded wire netting. Metal protectors can also be obtained, but they have the disadvantage of tending to obscure the view.

Low-water Alarms.—One device consists of a steam whistle, operated by means of a pivoted lever attached to a float within the boiler; when the water gets low, the valve opens and the whistle blows. Another method consists of a low-water safety valve, actuated by a similar float and mechanism; at low water the valve opens and the escaping steam gives warning, at the same time reducing the pressure in the boiler. These valves are often combined with high-pressure safety valves. A low-water alarm is an additional safeguard if kept in working order and carefully adjusted so that the float rests upon the top of the flue when the boiler is empty; should the float become reduced in weight the counterbalance should also be reduced. Metal floats should be used instead of vitrified brick if the water has a corrosive action on the brick. The alarm or low-water safety valve should be tested whenever a boiler is blown off for stoppage; as soon as the water gauge indicates less than ½in. of water in the glass, the whistle should sound or the low-water safety valve should blow.

INSTITUTION OF MINING AND METALLURGY.

THE 22nd annual general meeting of this Institution was held on the 13th inst. in London. The retiring president, Mr. Edward Hooper, occupied the chair, and announced the changes brought about by the ballot for officers in the ensuing year. In their report for last year the Council had pleasure in intimating the unabated progress of the institution, and even with the advanced standard of qualification 150 new members were admitted last year, thus bringing the total to 2,258. The Council had to take action in several cases of the use of the institution initials by unauthorised persons, and with a view to strengthening their position the Council are seeking State recognition to the extent of incorporation by royal charter. The statement of accounts showed an excess of income over expenditure of £303; and £258 had been paid out of a special fund for prizes and research scholarships, which were presented at the meeting. The "Goldfields" medal was awarded to Mr. C. O. Bannister for his researches on "The Blast-Roasting of Galena," and the premium of 40 guineas was given conjointly to Messrs. Hatschek and Simon for their paper on "Gels in Relation to Ore Deposition." The prize of 20 guineas for the best contribution to the transactions during the year was awarded to Mr. A. T. French for his paper on "Quick Combination Methods in Smelter Assays," and the students' prize of similar amount went to Mr. H. S. Ball for his research on "The Economics of Tube-Milling." Post-graduate scholarships of £50 each were given to Messrs. Cloutman, Eyden, and Schuietma, of Carnborne; and in addition 12 post-graduates were selected for courses of study abroad. After the customary votes of thanks had been accorded, the newly-elected president, Mr. B. M'Neill, delivered his presidential address.

Explosion of a Vertical Boiler.—While two men were standing near a vertical boiler at the British Oil and Cake Mills, Ltd., Trafford Wharf Road, Manchester, on the 18th inst., one of the tubes in the boiler suddenly burst, seriously injuring both men, one of whom subsequently died.

PROTECTION AGAINST POISONOUS GASES IN MINES.

AT a recent meeting of the Midland Institute of Mining, Civil, and Mechanical Engineers, Mr. H. C. Jenkins, in a paper on "Some recent experiments with internal pressures in pneumataphors," described an improved breathing apparatus for use in rescue work in mines. The author dealt with a point raised by Prof. John Cadman, who recently drew attention to a possible source of danger in connection with pneumataphors to which an injector was fitted, namely, that it was possible in case of an unsuspected leak to draw poisonous gases into the apparatus, which might cause fatal results. Mr. Jenkins described a simple contrivance devised by him in conjunction with his firm with the object of overcoming this difficulty. He said the object sought to be attained was the elimination of the zone of negative pressure, and to accomplish this it seemed a simple matter to provide a reservoir of air at plus pressure which would more than balance the tendency to negative pressure on the suction side of the injector. Such a reservoir was easily obtained by inserting a sort of envelope between the oxygen cylinders and regenerator and the back of the wearer, which envelope was inflated to the required extent by the pressure inside the apparatus, and remained inflated so long as there was no leak on the apparatus. The moment that a leak occurred the envelope ceased to be inflated, and the wearer was at once conscious that something had gone wrong, and he could then make his way back to safety before he might have taken into his system sufficient of the outside gases to render him unconscious. In ordinary working, the air in the reservoir or bag maintained a plus pressure throughout the apparatus. It was an absolute impossibility for the bag to fill when any leak was present in the apparatus.

METAL QUOTATIONS.

TUESDAY, MARCH 25TH.

Aluminium ingot	95/- per cwt.
" wire, according to sizes, &c. ......from	112/- "
" sheets " " ...... "	120/- "
Antimony ......£33/-/- to	£36/-/- per ton.
Brass, rolled	8½d. per lb.
" tubes (brazed)	10⅛d. "
" " (solid drawn)	9d. "
" " wire	8⅝d. "
Copper, Standard	£64/12/6 per ton.
Iron, Cleveland	64/10½ "
" Scotch	70/10½ "
Lead, English	£16/15/ "
" Foreign (soft)	£16/2/6 "
Mica (in original cases), small	6d. to 3/- per lb.
" " " medium	3/6 to 6/- "
" " " large	7/6 to 11/- "
Quicksilver	£7/10/- per bottle.
Silver	26 1/16 d. per oz.
Spelter	£24/12/6 per ton.
Tin, block	£211/-/- "
Tin plates	14/- "
Zinc sheets (Silesian)	£28/-/- "
" (Stettin; Vieille Montagne)	£28/2/6 "

Home Office Report on the Ilkeston Gasholder Explosion.—The Home Office have just issued the report by Mr. A. G. Drury, M.Inst.C.E., Engineering Inspector of the Local Government Board, on the causes of the circumstances attending the accident which occurred to a gasholder at the Ilkeston Corporation gas works on January 8th, 1912. The inspector, in his conclusions, says, "Although it has not been possible to say definitely how and in what manner the accident at Ilkeston occurred, I think that the facts disclosed by the enquiry show that it is by no means unaccounted for, and that had the tank not been structurally weak the result of such an occurrence as the temporary jamming of the holder or the unsealing of a lift would probably have been confined to a loss of gas and damage to the holder itself. The Town Council were somewhat ill-advised in not calling in a specially skilled engineer to advise them in the choice of a design, and the initial mistake made was the acceptance without question of a specification and design from a manufacturer in competition with other firms." The inspector condemns the practice as based on a false economy, and suggests that in such cases as these the designs, calculations, and specifications should all be checked by an expert.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Furnace grate for locomotive boilers. Hill. 26100.

Dredgers. Reid, Mavor, and Mavor & Coulson, Ltd. 27159.

Apparatus for discharging condensed steam water from steam condensers. Morison, and Contraflo Condenser and Kinetic Air Pump Company. 29259.

1912.

Process for improving the lubricating power of oils. Lecocq, D'Orimont, & D'Orimont. 2382.

Internal combustion engines. Boyd. 2521.

Carburetters for internal-combustion engines. Claudel. 2752.

Heating apparatus employing liquid fuels. Wyss. 2855.

Means for locking nuts. Bauer. 5016.

Apparatus for automatically analysing a gas, or gaseous mixture, volumetrically and recording the same. Woodroffe & Boultbee. 5039.

Gas-producer systems. Marks. 5080 and 22722.

Jigs for washing coal and ores. Munby. 5199.

Toothed gearing. Dawson & Buckham. 5310.

Pit and shaft sinking. Walker & Liddell. 5423.

Means for regulating the temperature of igniting chambers for internal-combustion engines. Debrunner. 5582.

Steam evaporators. Quiggin. 5587.

Direct acting fluid engines of the positive action type. Anthony. 5594.

Sprocket chains. Wayson. 5668.

Production of water gas. Choury. 5742.

Construction of ships. Harroway. 5804.

Speed-indicating instruments controlled or governed by timekeeping mechanism. Clarke, and Chadburns (Ship) Telegraph Company. 5823.

"Either side" brake mechanism for railway wagons. Adams and Bythway. 5827.

Apparatus for use in the coaling of ships. Robertson. 5883.

Manufacture of screw-nuts. Mucklow. 5916.

Steam generators. Bone & McCourt. 5936.

Process for avoiding shrinkage cavity or pipe in ingots. Hoyle and Brearley. 5951.

Internal flues of steam generators. Webster. 6340.

Turbines, turbine pumps, or turbine compressors. Gill. 7321.

Means for raising sunken ships. Parsons. 7360.

Apparatus for loading and trimming vessels. Boult. 7570.

Transmission gear for motor cars. Liddell. 7878.

Screwing machines. Winn, Cox, & Brenchley. 7952.

Combustion product engines. Kingston. 8035.

Urgency braking valve for air brakes. Rosenberg. 8388.

Planimeters. British Thomson-Houston Company. 8526.

Apparatus for compressing air. Stokes. 8863.

Timing gear for the admission of liquid fuel in internal-combustion engines. McKechnie. 8870.

Reversing gear for internal combustion engines. McKechnie. 8895.

Explosion engine with two opposite cylinders and rigidly connected pistons. Lelarge. 9286.

Means for starting explosion engines. Payne. 9482.

Centrifugal fans and pumps. Hardy. 9489.

Compressed air starting device for motors. Jorgensen. 10218.

Structure of steamships. Oswald. 10867.

Feed water heaters of locomotive boilers. Margery. 11216.

Means for opening and closing gates used in lifts. Electromotor Equipment Company, and Archer. 11500.

Dynamometers for measuring the twist of shafts. Cummings. 11902.

Controls for aeroplanes. Ray. 11905.

Means for testing the sparking plugs of internal combustion engines. Mackay. 12672.

Clutches and variable speed gearing. Fippard. 12922.

Screw propellers. Giessmann. 13312.

Wind and water-current motors. Watson. 13417.

Furnaces. Leinveber. 13986.

Internal combustion engines. Boyd. 14217, 14218, and 14219.

High pressure steam heating systems. Bousfield. 16697.

Tidal motors. Mould. 18101.

Governors for internal combustion engines. Soc. Deville & Co. 18531.

Manufacture of fuel briquettes. Furse. 18736.

Mechanism for controlling epicyclic variable speed gears. Defordt. 19597.

Turbines. Bergmann Elektricitäts Werke Akt. Ges. 20835.

Hydraulic valve operating mechanism for internal-combustion engines. Lamplough, and D. Napier & Son, Ltd. 20953.

Ore feeders. Waters & Cawthorne. 21110.

Means for signalling on trains and for stopping same independently of the engine driver. Emmett. 21723.

Device for protecting explosion engines against the results from back firing. Wilders. 21836.

Tubular air heating apparatus. Keith & Bain. 22097.

Change speed gear. Marti, and Motorwagenfabrik "Berna" Akt. Ges. 22104.

Lubrication of engines. Prestwich. 22346.

Integrating and recording mechanism for rate of flow meters. Hodgson. 22370.

Railway rail. Heroux & Milette. 22727.

Ships. Dingwall. 22759.

Apparatus for purifying water by heating. Savary Carlier. 23522.

Ball cages for ball bearings. Kugellagerwerke J. Schmid Roost Akt.-Ges. 23925.

Centrifugal clutches. Robertson. 24833.

Clutch controlling gear. Boult. 24888.

Driving keys and key ways. Tullis. 25620.

Gas producers. Crossley & Fielden. 26128.

Self closing and emergency stop valves. Cockburn & MacNicoll. 26421.

Machine for grinding worm. Brown & Bostock. 27694.

Metallurgical furnaces. Greenawalt. 28411.

Lubricators. Bettaque. 29271.

1913.

Coke ovens. Hohmann. 1569.

Means for converting reciprocatory into rotary motion and vice versâ. Pitts. 1626.

ELECTRICAL, 1911.

Starting and speed control gear for use with electric motors. Mascord. 26864.

1912.

Electrically operated telphers and tracks therefor. Strachan, and Strachan & Henshaw, Ltd. 190.

Automatic and semi automatic telephone circuits. Siemens Bros. and Co. 2320.

Electrical condensers. British Insulated and Helsby Cables, Ltd., and Bayles. 2701.

Metal vapour alternating current rectifiers. Hartmann & Braun Akt. Ges. 5345, 5415, 18603.

Electrical signalling apparatus. Potts. 6050.

Holders for electric lamps, switches, &c. Muller. 6395.

Manufacture of incandescent electric lamp filaments. Jahoda, and Elektrische Gluhlampenfabrik "Watt" Scharf Löti and Latzko. 7977.

Method of charging storage batteries. Wilson. 9593.

Telephones. Killar & Grove. 9714.

Rotary converters. Mackie. 10804.

Oscillation gaps or dischargers for use in radio telegraphy and radio telephony. Torikata, Yokoyama and Kitamura. 10823.

Repulsion motor with divided stator winding. Maschinenfabrik Oerlikon. 11434.

Telegraph systems. Pope. 11604.

Instruments for measuring or controlling the frequency or wave length of alternating currents, or for indicating speed. Seibt. 16871.

Electrical generating set. Rey. 18025.

Telephone system. Baumann. 18677.

Chemical generators of electricity. Sozzi. 20101.

Telephonic transmitting appliance. Rhodes. 20196.

Brush holders for dynamos. Berdon. 20224.

Method of manufacturing electric incandescent lamp filaments. Bailey & McDowell. 20621.

Movable sleeve devices to facilitate the inspection of wires in electric cables. Williams. 21215.

Electrical indicating or alarm apparatus. Weikel & Weikel. 21939.

Electric cooking apparatus. Downe, and Brompton & Kensington Accessories Company. 25586.

Supports for metallic filaments of electric incandescent lamps. Gill. 26249.

Electrical switches. Wynne. 26517.

1913.

Trimming indicator for arc lamps. Korting & Mathiesen Akt. Ges. 253.

The New Floating Dock for the Admiralty.—The floating dock which is provided for in the new Naval Estimates is to have a lifting capacity of about 40,000 tons, and will therefore be the largest structure of the kind ever built in this country.

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Edited by
WILLIAM H. FOWLER
Wh. Sc., M.Inst.C.E.

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Coal Contracts on a Calorific Basis.

Although coal is one of the largest items in the trade account of most manufacturing establishments, the methods of purchasing it are often lax and unbusinesslike. Manufacturers who institute rigorous tests and checks in the purchase of commodities generally accept with little or no demur variations from stipulated quality in the case of coal which they would not for a moment tolerate with other materials. This appears to be due partly to innate conservatism and a feeling of helplessness arising from a belief that satisfactory tests are so difficult and troublesome as to be scarcely worth making, and partly to the fact that until recent years coal in most places was exceedingly cheap and slight variations in quality not worth quarrelling about. Keener trade competition and the great increase in the price of fuel within recent years have tended to modify these views, so that the purchase of coal to a specification, based mainly on tests of its calorific value and other qualities, is now a more frequent incident of fuel contracts than formerly, though the practice is still far from being as common in this country as in the United States and on the Continent. Opposition to this method of purchase has not been due to users only. A good deal of opposition and prejudice has characterised the attitude of colliery proprietors and middlemen, and it must be admitted that when large contracts are concerned many commercial considerations have to be borne in mind, besides the intrinsic qualities of the coal itself, so that an equitable standard specification is not quite so simple a matter as might appear at first sight. Coal is not a manufactured article, and it is not possible to secure absolute uniformity in deliveries. It may differ greatly in quality from the same colliery owing to the output being the product of several seams, and may even vary considerably from the same seam. There are many disturbing influences, in fact, over which the producer can exercise little control, so that some latitude is essential. Apart from these, there are other matters in a coal contract

which may lead to troubles and disputes. Both coal producers and users have in the majority of cases to rely upon public carriers for the conveyance of the commodity, and questions of demurrage, loss of weight in transit, may easily afford openings for differences, not to mention interferences arising out of labour troubles. These various matters do not, of course, affect the calorific basis of purchase, but it is evidently to the interests of both parties that some standard of reference in regard to the other matters named should if possible be adopted. The need for this has for some time been particularly felt in the London district, and for this reason special interest attaches to the agreement which has been arrived at, after prolonged discussion between the Associated Municipal Electrical Engineers of Greater London on the one hand and representatives of coal contractors on the other, since in its general outlines it would probably serve as a model for similar agreements elsewhere. We give on another page the more important clauses of the standard specification, and it may be of convenience if we point out here the salient features. Coal may be supplied to two alternative specifications: (*a*) For coal of a particular description or "named" coal; (*b*) for coal of guaranteed physical qualities for steam-raising purposes. In respect to the latter, samples are to be taken from each consignment and tested by the purchaser, or, in the event of dispute, by an independent expert, paid by the contractor if the purchasers' tests are confirmed. No alteration of the contract price, however, is to be made unless the variation from the calorific standard exceeds 5 per cent. up or down from the figures given in the table of standard qualities. If the variations exceed this then the price per ton is increased or diminished, according as the calorific value is greater or less than the standard beyond the 5 per cent. limit, though the purchaser has the right to reject the whole consignment if the calorific value is more than 7½ per cent. below the published standard. A similar modification of price up or down is made for any variation in the standard percentage of moisture. Modifications are also made in the price for variations in size. If, for example, the percentage of smalls be less than the standard the price is increased by certain defined methods. In the calorific tests, the thermal units are ascertained on coal dried at 220° Fah. for an hour by means of a Mahler Bomb Calorimeter. Moisture is represented by the total loss in weight after air drying and exposing to a temperature of 220° Fah. for one hour, while the percentage of sulphur is based on the analysis of the coal as received, and is not to exceed 2 per cent.

Sleeve Valve Internal-combustion Engines.

The long litigation between Messrs. Knight & Kilbourne and Argylls, Ltd., arising out of the patent respecting Knight's valveless engine, was brought a step nearer final decision by a judgment in the Court of Appeal last week. The patent, which claimed to cover every possible application of sleeve valves to internal-combustion engines, it may be remembered, was argued at great length before Mr. Justice Neville, who gave judgment in favour of the defendants, which has now been confirmed on appeal. The basis of the action was not the patent under which the Knight sleeve valve engine was actually constructed, but an earlier patent, which, though it admittedly described in detail only an inferior method of constructing a sleeve valve engine, was nevertheless claimed to be a master patent, and it was asserted the defendants' engine embodied only subsidiary improvements. In the patent which formed the basis of this claim there was but a single sleeve and only a plain rectilinear motion, whereas the defendants give to the sleeve a combined linear and rotary motion. The Court of Appeal held that if the patent sued on was to be taken as covering the general principle involved it had been anticipated by still earlier patents of Dawson and King. Further, they held a master patent could not be constituted by construing the specification as stating the problem to be solved, but that the inventor was bound to give his specific solution, and the solution described in the patent was, in their judgment, not infringed by the defendants. So far as the judgments in this case have gone, it is clear that the application of sleeve valves to internal-combustion engines is open to anyone, and that the only patentable features are the special methods of operating it, and these obviously may vary considerably.

THE EFFECT OF SULPHUR ON COPPER.

In the current issue of "The Brass World," Mr. Erwin S. Sperry gives the results of some experiments, showing the effect of sulphur on copper. All fuels, he observes, whether coal, coke, oil or gas, contain more or less sulphur, and in the case of coke or coal, at the present time it is usually "more." The quality of these fuels does not appear to be growing better. As all fuels contain sulphur, and copper and its alloys have an affinity for this element, it is quite natural to presume that each time metal is melted it absorbs some of it, and it actually does. The singular fact, and one that produces such unsatisfactory results, however, is that each time metal is melted, a greater or less amount of sulphur is absorbed from the products of combustion, and it remains in it, as it will not free itself or become oxidised out in any subsequent melting. In other words, the sulphur is constantly increasing as the metal is melted over and over again. Little attention has been given to the presence of sulphur in the brasses and bronzes. The average analysis never shows it, although it has an important bearing upon the subject, and should always be determined for a complete analysis. It seems to influence the casting qualities and the colour of the cast surfaces, and, in addition, appears to cause blowholes. Just how much sulphur can be tolerated in brass or bronze has yet to be determined, and nothing seems to have been done to determine it. As a matter of fact, it has only recently been appreciated that sulphur is quite an injurious element in these metals. Apropos of this fact, the following experiments on the effect of sulphur on copper, made some time ago, may be of interest. While they do not determine the effect of sulphur on the brasses in the form of sand castings, they may serve to indicate some of the irregularities that take place when sulphur is present in copper to a greater or less extent.

Experiment No. 1.—Melted 10lbs. 5oz. of Lake Superior copper in a graphite crucible in an anthracite coal fire in the usual manner. Kept covered with charcoal when the melting was taking place in order to prevent oxidation as much as possible. When melted and at the heat ordinarily used for adding zinc to it to make brass, 4ozs. of lump sulphur were introduced. This was added in small pieces at a time, and the crucible shaken after each addition. It was not stirred, as it was desirous of avoiding the introduction of any iron. The metal was then poured into small strip ingots in an open mould. The copper ran well and apparently as thin as it would were no sulphur present. The sulphur did not seem to render it sluggish at all. The metal smelled very strongly of burning sulphur while it was being poured, and bubbled with a sort of effervescence. The metal set readily without any swelling or expulsion of gas. The tops of the cooled ingots were covered with a black scale like ordinary copper. The copper was rather brittle and broke easily, with a short fracture, and blowholes were present in it. The copper had a peculiar red shade, rather inclined towards a light bronze, or perhaps like that of a red brick had it a slight metallic lustre. The copper seemed to cut like a poor leaded brass, and the chips were short. It was wholly unlike the ordinary copper, with its unsatisfactory cutting qualities. An analysis of the copper showed 1·06 per cent. sulphur.

Experiment No. 2.—The next experiment was practically a repetition of the one just described, and is of interest as indicating that the copper apparently took up nearly the same amount of sulphur. In a graphite crucible in the manner previously described were melted 17lbs. 14ozs. of Lake Superior copper and 15ozs. of lump sulphur added in small pieces at a time and the copper stirred with a graphite stirrer. Poured into an open mould in the form of strip ingots. Smelled very strongly of burning sulphur while being poured. While the ingots were "setting," a sort of effervescence took place at the top. There was a "sizzling" sound, and gas appeared to escape, though it could not be seen. The sound, however, was apparently produced more by chemical action than otherwise on account of the separation of sulphide of copper on the top of the ingots on cooling. The copper ran well, and did not seem to be sluggish. The metal was short and the fracture light coloured and slightly crystalline fibrous. While the copper could be bent a little before breaking, it was quite short. The fracture contained blowholes. An analysis showed sulphur 1·04 per cent.

A peculiar feature of this experiment was the fact that, after cooling, the ingots were all covered with a thick, black scale, which proved to be sulphide of copper. This scale was about an eighth of an inch in thickness, and could readily be separated from the metal. The line of separation between the ingot and the scale was very distinct. This scale formation and separation were apparently the cause of the "sizzling" sound heard during the cooling of the ingots. A remarkable thing in this experiment was the fact that the amount of sulphur in the copper was practically identical with that in the first experiment, although a much greater quantity of sulphur was used. This fact would appear to indicate that only a certain quantity of sulphur will combine with copper, and that this amount is about 1 per cent. If more sulphur is added it combines with the melted copper, but separates out while cooling in the form of copper sulphide. Copper, I believe, from these results combines with a definite amount of sulphur.

Experiment No. 3.—Melted 21lbs. of Lake Superior copper as before, and then added 24ozs. of sulphur. Poured into ingots. The metal bubbled strongly while being poured and smelled strongly of sulphur dioxide gas, so that the pouring was difficult on account of these irritating fumes. The fracture of the ingot contained blowholes. The ingots did not shrink or swell, and "sizzled" while cooling. When cool, it was found that they were covered with the black scale, as in experiment No. 2. This scale was analysed, and found to contain copper 80·31 per cent. and sulphur 19·69 per cent. This indicates that it is the cuprous sulphide as this compound contains, theoretically, 79·84 per cent. of copper. The cupric sulphide contains 66·45 per cent. of copper. An analysis of the copper showed 0·89 per cent. sulphur. The effect of forging upon the copper is of interest. When heated red hot, it smelled strongly of sulphur dioxide. If the copper were heated to a good red heat, or what would be called a high rolling temperature, it could be bent over on itself and flattened without cracking; but if the heat were low, or the so-called low red heat, it cracked, even when bent slightly.

Experiment No. 4.—The effect of lower percentages of sulphur was next tried, and 5lbs. of Lake Superior copper and 5lbs. of the copper obtained in Experiment No. 2 (1·06 per cent. sulphur) were melted together, and then poured into ingots. This gave copper as follows: Copper 99·47 per cent., and sulphur ·53 per cent. The copper ran freely without any film of oxide on the surface, and the ingots did not shrink or swell. They "sizzled" while cooling, like the ones in the previous experiment. The ingots were softer than the previous ones, and would bend considerably before fracturing. The fracture was fibrous crystalline. The ingots contained blowholes in the fracture. In forging the metal behaved peculiarly. It could be flattened well at all heats, but if bent, even 15° or 20°, it cracked. This cracking when bent took place at all heats, and is apparently a characteristic of copper containing sulphur.

Experiment No. 5.—Melted 9¼lbs. of Lake copper and 3lbs. 1⅓ozs. of the copper obtained in Experiment No. 2 (containing 1·06 per cent. sulphur). Poured into ingots. This mixture gave the following sulphur content, figured from the sulphur in the copper used, and an analysis was not made: Copper 99·74 per cent., sulphur ·26 per cent. The ingots remained level after cooling, and although they "sizzled" while this was taking place, it was not as violent as in the case of the copper containing more sulphur. The fracture of the ingots showed blowholes. In forging, it smelled of sulphur dioxide while red hot. The forging properties were exactly like those of the preceding experiment, and the ingot, although it could be flattened out under the hammer, would not stand bending at any heat, even to a slight degree. When flattened out under the hammer, very few edge cracks could be seen, and these only when the edge became quite thin.

Experiment No. 6.—A mixture of 12lbs. of Lake copper and 1lb. 5¼ozs. of the copper obtained in Experiment No. 2 (containing 1·06 per cent. of sulphur) were melted together. When poured, it ran more sluggish than the copper in the previous experiments (containing more sulphur). In cooling, however, the ingots "sizzled" more strongly than in any of the other experiments, and the tops of the ingots swelled. When this "sizzling" was taking place, sulphur dioxide gas was given off very strongly. When the metal was poured it smelled strongly of this gas. The mixture as made would show the following: Copper 99·90 per cent., and sulphur ·10 per cent. The fracture of the ingots was filled with blowholes some of them very large. In forging, the copper could be forged to a thin edge, but at any heat would not stand bending, even to a slight degree, without breaking. Although the other samples of copper smelled of sulphur dioxide when heated for forging, this sample did not manifest this peculiarity.

Experiment No. 7.—The copper obtained in the last experiment was re-melted and poured into ingots again. It behaved exactly the same. The ingots "sizzled" and swelled, and the fracture was full of blowholes. In forging, its behaviour was identical with that of the previous experiment.

Conclusions.—The conclusions reached from these experiments were the following: (1) That copper will not absorb over 1 per cent. of sulphur. If more is added to it, it separates out as cuprous sulphide on cooling. (2) That sulphur causes blowholes in copper. (3) That it renders the copper red short, particularly when bent. (4) That it produces a crystalline fracture when present in considerable quantity.

International Mining and Metallurgical Congress.—One of the largest of the great scientific and industrial congresses is to be held in London in the early part of June, 1915. This is the sixth international congress of mining, metallurgy, applied mechanics, and practical geology. These congresses take place at intervals of five years, and the last was held at Dusseldorf in 1910. An influential committee has been formed to make the necessary arrangements, and the movement is being actively supported by the University of London, Imperial College of Science and Technology, the various leading technical and scientific societies, and by numerous firms interested in the various industries represented.

Large Impulse Water Turbines.—What are stated to be the largest impulse turbines ever constructed have been installed in the Pirahy plant of the Rio de Janeiro Light and Power Company. There are two of these machines, and they are each capable of generating 20,000 h.p. They are operated at 300 revs. per minute by water jets having a velocity at the nozzles of 235ft. a second. The circumferential speed of the runner is 108ft. a second. Each unit has a single runner with pear-shaped buckets of heavy design. The wheel is keyed on to the end of the shaft and equipped with four jets placed 90° apart. The jets pass through cast-steel nozzles, carefully machined and polished to reduce friction losses, and their discharge is controlled by means of movable steel needles with pear-shaped heads, which, on being moved, enlarge or diminish the diameter of the jet. The four needles are connected and move simultaneously, and their movement is controlled by an oil pressure governor.

HUGHES' SUPERHEATERS FOR LOCOMOTIVE BOILERS.

The superheaters shown in the accompanying illustrations, designed and patented by Mr. George Hughes, M.Inst.C.E., of Wingfield, Heaton, Bolton, are applicable to locomotive and other smoke or flue tube boilers. Referring to the arrangement shown in Fig. 1, D are the enlarged flue tubes for receiving the superheater elements and A the ordinary smoke or flue tubes. B is the saturated steam receptacle or header, secured in the usual position on the upper part of the smokebox tube plate of the boiler, and is in communication with the steam pipe from the regulator. This saturated steam receptacle or header is provided with a number of branches, P and H. These branches receive the inlet ends C of the superheating elements or pipes J, which are secured to the branches in any suitable manner. For instance, the superheating element ends C might be provided with flanges F, by which they could be secured to the branches P and H by means of bolts or studs. Each superheating element J is bent as shown, so that it enters one of the enlarged smoke tubes D; it is continued along this smoke tube D to within a short distance of the firebox, where a return bend G is provided. It then returns along the smoke tube D, and takes a downward bend to the superheated steam chambers E. The superheated steam

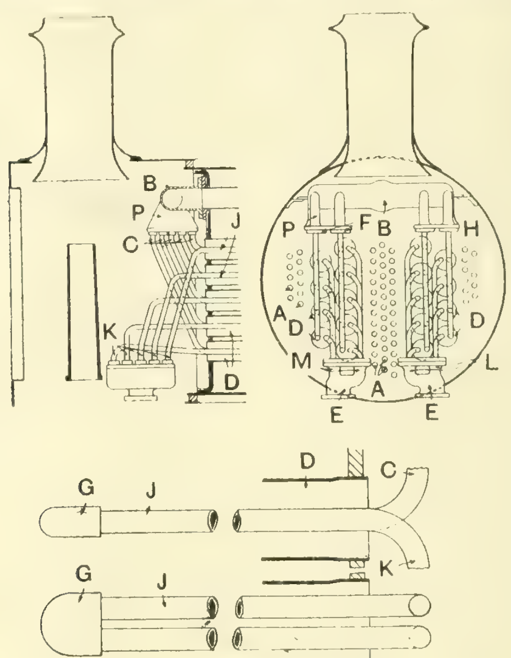


Fig. 1.—Hughes' Superheater for Locomotive Boilers.

receptacle or collectors E are secured to the upper sides of the steam chests of the engine. The outlet ends K of the superheating elements are secured to these collectors in a manner similar to that described with reference to the attachment of the saturated steam inlet ends C of the elements. The superheated steam receptacles or headers E are provided with branches L and M, to which the elements are secured. The saturated steam leaving the boiler enters the saturated steam receptacle or header B, from whence it passes through the branches P H, along the superheating elements J, and through their outlet ends K to the superheated steam receptacles E, the superheated steam entering the receptacles through their branches, respectively M L.

Referring to the arrangement shown in Fig. 2, the saturated steam receptacle or header B is similar to that described in Fig. 1, E being the branches to which the inlet ends C of the superheating elements J are secured. The superheated steam receptacle or header E in this case, however, is formed as a single casting, so as to communicate with the steam chests of the engine. This, it is claimed, is advantageous in that the full supply of superheated steam is available for either cylinder when the valve is open for admission. The superheating elements J are run in a similar manner to that described with reference to Fig. 1, either two or four runs of pipe being within each smoke tube D. The lower illustration in Fig. 2 shows the method by which four runs of pipe are arranged to traverse each smoke tube, J being the superheating pipe and G the return bends which may be of any of the various known and suitable kinds.

In order to facilitate the withdrawal of either the saturated or superheated steam headers or receptacles for the purpose of making or remaking the joint between the headers or receptacles and the tube plate or the steam chest, respectively, withdrawable liner plates or distance blocks N O may be employed (see Fig. 3). These liner plates or distance

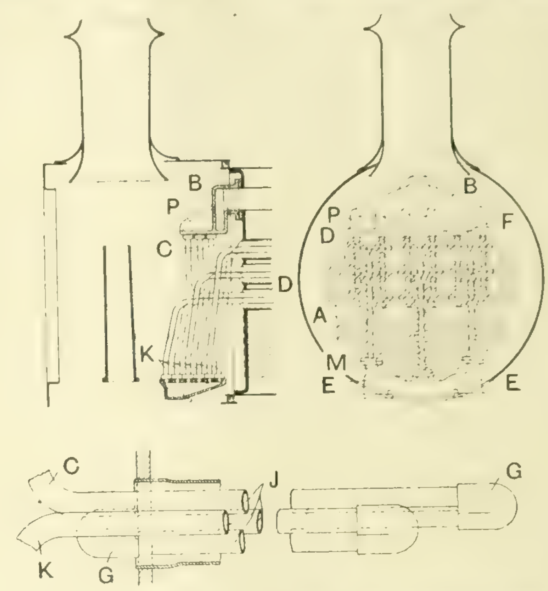


Fig. 2.—Hughes' Superheater for Locomotive Boilers.

blocks are placed between the superheater element flanges and the header or receptacle, and are made in such a manner that when they are removed there is sufficient clearance between the flanges of the superheater elements and the header to allow the latter to be lifted clear of the studs by which it is secured to either the tube plate or the steam chest, thus avoiding the necessity of disturbing the element when removing the headers.

The saturated and superheated steam receptacles or headers being separate chambers or castings of simple design

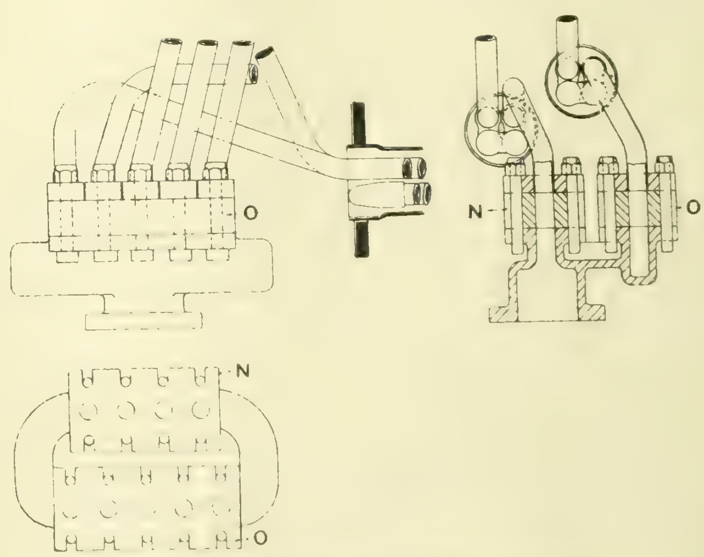


Fig. 3.—Hughes' Superheater for Locomotive Boilers.

they can be produced and fitted in an economical manner. Further, the saturated and superheated steam receptacles or headers, B and E, respectively, being widely separated from each other, and the usual smokebox steam pipes being dispensed with, loss of superheat during the passage of the superheated steam from the outlet ends of the superheater elements or pipes to the engine valve chests is, it is claimed, reduced to a minimum as compared with superheaters of the types now generally used.

POWER SUPPLY ON THE RAND.*

BY A. E. HADLEY.

The Victoria Falls and Transvaal Power Company, Ltd., was formed at the end of 1906, with the object of supplying power in South Africa and Rhodesia, and of acquiring the concessional rights to develop the Victoria Falls. Under the original proposal a supply to the Rand was to be given partly by transmitting power from the Victoria Falls, 700 miles distant, and partly by steam-generating stations located on the reef. The increase in the coal supplies in the Transvaal bringing about a reduction in the price of local fuel, the necessity for starting operations without any delay, and the objections raised by various vested interests to the importation of power from outside the Colony, were among the principal reasons for delaying the development of the falls until the population of Rhodesia increases or until the demand in South Africa for manufacturing sites with cheap electric power available justifies the expenditure. It was therefore decided to supply the Witwatersrand from steam plant using local fuel.

Electric Power on the Rand.—The Victoria Falls Company took over the two existing supply companies in 1907, and purchased the Vereeniging wayleaves, at the same time entering into an agreement for the right to establish a power station at Vereeniging. In 1907, pending the installation of modern plant, a supply totalling 4,000 kw. was given from the existing steam stations which had been purchased. As soon as it was appreciated that a cheap power supply was available, the mining groups entered into contracts with the company, and the demands for power have since increased so quickly that it has throughout been the greatest difficulty for the company to raise capital and install plant rapidly enough to satisfy the demand. In addition to the supply of electricity to this group of mines, the conditions called for the supply of compressed air for working the rock drills.

The peak load of the combined undertaking has reached 88,000 kw., and the sales average 1,350,000 units per day. These figures include the sales of compressed air by the Rand Mines Power Supply Company to 10 mines. The air units represent practically the same amount of energy as if these 10 mines had converted their compressors to electric drive and purchased electricity. When the further demands for power which have already been notified are met by the plant now on order, the sales will reach 2,000,000 units daily. The monthly load factor, based on the hour of maximum output, varies from 70 to 74 per cent.

Table I.

Name of Station.	Total Capacity of Electric Generating Plant Installed.	Steam-driven Air Compressors Installed.	Extensions in Progress.
Brakpan	Two 3,000-kw. sets		
Simmerpan	Six 3,000-kw. sets	—	—
Rosherville	Five 10,000-kw. sets	Six 3,500-kw. machines	Three 7,000-kw. steam-driven air compressors
Vereeniging	Four 10,000-kw. sets	—	—
Extensions in 1913 ...	—	—	Two 10,000-kw. sets
	114,000-kw.	21,000 kw.	41,000 kw.
Total capacity of plant installed and in progress		176,000	

The supply is furnished to all mining consumers at 2,100 volts and 525 volts. The necessary step-down transformers and switch gear are provided by the power company, while the consumer supplies the sub-station building and pays the power company a sum equal to 2 per cent. of the power bill to cover the losses in the step-down transformers. The standard price in mining contracts covering not less than 12 years is 0·525d. per unit, as long as the monthly load factor is above 70 per cent., the load factor being based on the hour of maximum consumption. The introduction of these prices on the Rand has reduced the cost of power to the mines by 40 per cent., and has reduced the cost of production of gold by an amount varying from 6d. to 1s per ton of ore milled. It has further resulted in considerable saving of capital expenditure on plant, which in the case of a new mine may amount to £100,000. The area over which a power supply had to be given lies within a strip of about two miles broad and stretching 50 miles from east to west. The total power used by the mines at the present time is estimated at about 400,000 h.p. The town of Johannesburg, which has its own electric plant, is situated about the middle of this strip, while the township of Germiston, about nine miles to the east, is supplied by the company.

* Abstract of paper read before the Manchester section of the Institution of Electrical Engineers.

Power Stations.—The local water supply conditions restricted the choice of the station sites to certain artificial lakes situated along the reef and to the Vaal River, which runs parallel to the reef and is 35 miles south. Power plants aggregating nearly 180,000 kw. have been installed in, or are under construction for, the stations enumerated in Table I.

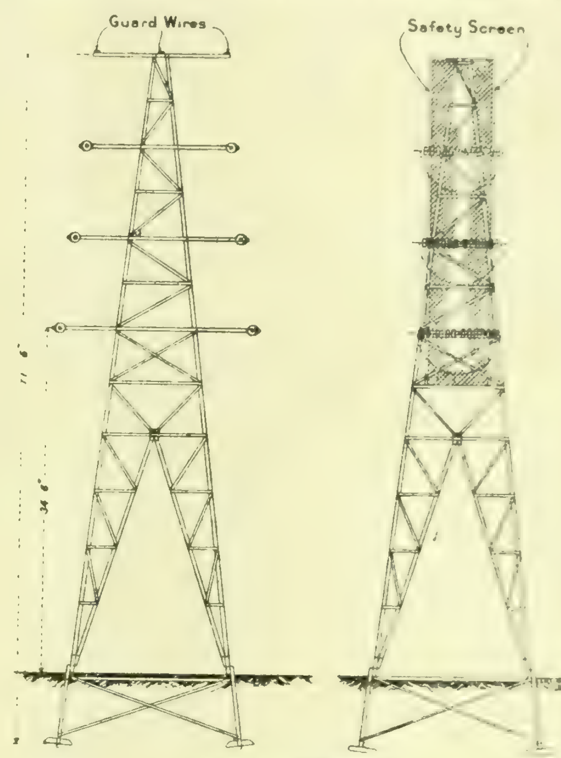


Fig. 1.—Anchor Mast

They are set out in the order in which they were built. At Robinson Central air station there are also six electrically-driven air compressors each of 3,500kw. capacity. At all stations steam turbo-electric generating sets are employed, and produce 3-phase energy at 50 cycles. Step-up transformers raise the generator pressure to 40,000, 20,000, or 10,000 volts, and their interposition gives additional security to the machines against pressure rises. This method, in which the generator voltage is optional, gives the further advantage of enabling the stators to be constructed with bar winding having one bar per slot.

Electrical Transmission System.—The main system of transmission is effected by means of 40,000-volt overhead lines stretching practically the whole length of the reef. At the present time, however, the western extremity is working as a 20,000-volt distribution line. Where the load is most dense the transmission system consists of two rows of towers, each arranged to carry two circuits. The 40,000-volt transmission system is fed at four points, viz., at Brakpan, Simmer Pan, Rosherville, and at Robinson Central, where the supply from the Vereeniging station joins the reef. In addition to these distribution stations the transmission lines pass through two further distributing centres at Hercules to the east and Bantjes to the west. From these six points distribution networks, laid out as ring mains, supply the various sub-stations

on the mines. The three eastern distribution stations supply the system through 10,000-volt overhead lines. The central portion of the area is served by an underground 20,000-volt cable system, and the western distribution network is working at 20,000 volts by overhead lines. The Vereeniging station is connected to the Rand by an 80,000-volt line, approximately 35 miles long, terminating at the Robinson Central distribution station, where the pressure is transformed to either 40,000 or 20,000 volts, these pressures being also coupled together through transformers aggregating 16,000 k.v.a.

80,000-volt Pole Line. This line consists of two rows of lattice steel masts equipped with four circuits of stranded copper, each conductor having a section of 60 sq. mm., and carrying three earthed guard wires above the conductors. Every fourth mast, commonly called an anchor mast (Fig. 1), is of sufficient strength to take the full strain of the conductors in a lateral direction; and the three intermediate masts (Fig. 2) are designed to take the strain due to wind pressure in a direction transverse to the line. Extra anchor masts are also used whenever the line changes its direction, and at railway crossings. A special end tower is used at the ends of the line. The masts are normally spaced 500ft. apart. The anchor masts have an overall height of 71ft. 6in., the lowest cross-arm being 34ft. 6in. from the ground. On these masts the conductors are placed vertically above each other, and are separated by a distance of 9ft. Each mast was required to deflect $\frac{1}{8}$in. at the top when subjected to a horizontal pull of $4\frac{1}{4}$ tons applied 44ft. from the ground at an angle of 30° from the line direction.

The intermediate masts, when carrying the weight of the insulators, conductors, and guard wires, were required to give a temporary deflection at the top of $\frac{11}{16}$in. when subject to a horizontal pull of 35 cwts., applied 35ft. from the ground and at right angles to the line direction. The conductors on these masts are arranged three on each side, in the shape of an equilateral triangle having sides 8ft. long. The lowest support for the conductors is 34ft. 6in. from the ground, and a 10ft. sag is allowed, so that the lowest part of any conductor is never less than 24ft. 6in. from the ground. All masts are provided with a safety screen to prevent any possibility of men working on one circuit coming into contact with the circuit on the opposite side of the pole. This screen consists of a rectangular steel framework interlaced with galvanised steel wire netting.

The 80,000-volt insulators used are of the disc type, 10in. diam., and connected six in series at each suspension and straining point. Before erection each insulator is subjected to a mechanical stress of $1\frac{1}{4}$ tons, and while in this condition is tested to 60,000 volts for five minutes. The latest type of 40,000-volt transmission line is of a similar design, but pin insulators are employed on the intermediate lattice masts, and four discs are used in each string of insulators on the main towers which take the lateral strain. All the 20,000-volt cables have circular conductors of 100 sq. mm. section, and are paper-insulated, lead-covered, and armoured. Each cable is capable of transmitting about 7,000 k.v.a. The cable was specified to stand a test pressure at the factory of 50,000 volts, and a test pressure of 40,000 volts for 10 minutes after laying.

Protective Arrangements. — All transmission and distribution circuits, with the exception of the long-distance 80,000-volt lines, are equipped with the Merz-Price balanced relay system for automatic switch control, without which a reliable supply on the ring main system could not have been given, and the more expensive radial type of network would have been necessitated. This balanced relay system is also employed for the protection of all transformers, and for the large generators. The pilot wires for operating this system on the 10,000-volt transmission lines are combined with telephone circuits in a lead-covered cable suspended overhead, while on all distribution net-works (both overhead and underground) combined pilot and telephone cable are laid underground.

Normal Control of Operation.—A complete telephone system has been installed, connecting up all points on the transmission and distribution system and the residences of the staff. A special feature of the lay-out of the telephone system is the arrangement whereby the control of all switching and the control and regulation of load, voltage, power factor, and other operating conditions are in the hands of the control department. Great importance is attached to the organisation whereby the control of the whole system when in operation is in the hands of this department, thereby greatly increasing the safety both of the engineering staff and of the supply. By means of this telephone system, one control engineer or load dispatcher is responsible for all routine switching and linking carried out at any point on the electrical system during his shift, and under the regulations no switching can be carried out without his consent. The load dispatcher, as soon as any switching has been carried out, adjusts a large diagram in the control-room, so that it shows every connection on the system.

Lighting and Atmospheric Conditions.—The atmospheric conditions on the Rand are in many ways abnormal, both in summer and winter. During the winter violent wind and dust storms are encountered, while for six months during the summer (from September to April) the reef is the centre of frequent and violent lightning storms accompanied by heavy rain and sometimes phenomenal hail. The Rand, which is the watershed of that part of South Africa, is probably about the worst district in the world for lightning, the altitude of Johannesburg being 5,760ft. At this altitude the range of temperature is very large, and rapid changes in temperature occur, disturbing the atmospheric conditions. Every storm exerts some influence of greater or lesser severity upon the overhead system, but year by year the number of troubles caused have been largely reduced, so that interruptions to supply are now infrequent, and the loss of apparatus seldom takes place. As a general rule the effect of lightning is brought about through an induced effect on the overhead lines, setting up a high-frequency surge. Experience goes to prove that the intensity of the induced effect is in the majority of cases localised to some part of the transmission line, and only in the minority of cases does it reach the end of the line with its full severity. Further, it is quite a rare though not unknown occurrence for the line to be actually struck by lightning; and it is possible, though not determined, that this may be the result of the earthed guard wires.

The means whereby the effects of lightning have been prevented in the great majority of cases from disturbing the system are mainly: (*a*) The employment of earthed overhead guard wires; (*b*) earthing the neutral of each separate section of the system; and (*c*) by careful selection and adjustment of lightning arresters to deal with the different conditions arising. When the supply was first started four years ago little accurate information existed regarding lightning arresters, consequently many interruptions of the service occurred, and apparatus was frequently damaged. In analysing the effects of any lightning disturbance, it has proved difficult to trace definitely the effect of any individual protective apparatus. Experience has shown, however, that the guard wire constitutes one of the most efficient systems of line protection, and contributes largely to successful operation during storms.

During the earlier lightning seasons the neutral of the system was not earthed, and unquestionably many interruptions and much loss of apparatus resulted from not employing this system. One of the troubles caused by lightning is occasioned by the arcing over of insulators, which, with an insulated system having considerable capacity to earth, generally results in an intermittent arc to earth, thereby setting up dangerous surges in the system. These surges lead to cumulative trouble and cause discharges on the arresters of the other two phases, increasing in severity until finally a second flash over takes place (generally at the arrester gear itself), and short-circuits the phases. By earthing the neutral through a resistance, any arc to earth is immediately isolated by the operation of the Merz-Price balanced relay system, and the arresters are not called upon to continue operating. A star-delta transformer is employed for earthing to avoid disturbance to telephones.

At the time of the initial installation the aluminium arrester was not on the market, and in consequence a complete system of horn arresters was connected up. The most careful records have since been kept of the operation and discharges

occurring on these arresters. The number of pressure rises on each of the phases with an earthed neutral has been found to be equal, and of 2,100 discharges recorded between October, 1910, and April, 1912, 33 per cent. occurred on each phase. The best combination of the number of horns, the spacing of arc gaps, and the amount of resistance to earth, had to be determined by experience and experiment. During last season some aluminium arresters were installed, but no conclusive observations of their operations were obtained. This system, however, has been adopted for the protection of the 80,000-volt lines.

Rosherville Power Station.—The site for the station was selected at the Rosherville Dam, which is the largest lake on the Rand, being enclosed on the southern side of a dam. The coal-storage arrangements are very complete, the coal being discharged from a height of 14ft. through the floors of 40-ton railway trucks into outside storage bunkers, under which coal conveyers are arranged. The whole structure is open, as roofing is unnecessary owing to the favourable climatic conditions. The conveyers, each capable of dealing with 40 tons of coal per hour, run in tunnels under the external coal store, and are fed with coal by gravity through shoots from the coal pile above. Weighing machines are installed in the conveyer tunnels, and the coal is weighed as it passes in the conveyer buckets. The ashes are discharged from the rear of the stokers into hand trucks in the basement. The coal has an average calorific value of about 11,000 B.Th.U. per pound.

The large percentage of ash, viz., 18 to 25 per cent. of the coal, and the high load factor at which the plant is operated, necessitated a combination of boiler, superheater, and economiser, that would give the highest possible efficiency; and the high cost of white labour, and the inefficiency of that of the native, also required that the plant should be mechanically operated. In view of these considerations and the great cost of constructional work in South Africa, the ejector system of induced draught originally devised by Mr. Pratt has been adopted in all the power stations. The system has been found to give the utmost satisfaction. The boiler unit selected is the Babcock & Wilcox marine type, fitted with chain-grate stokers, each having an integral superheater and economiser. The boilers are arranged in two rows in each boiler-house, with a central and common firing floor. Each boiler has a rated capacity of 32,000lbs. of steam per hour at a pressure of 220lbs., with a temperature of feed water at 100° Fah., and is capable of producing 38,000lbs. of steam without undue forcing. The heating surface of the boiler is 5,520 sq. ft., of the superheater 1,720 sq. ft., and of the economiser 2,200 sq. ft. A six-hour test on one of the boiler units gave a combined efficiency of boiler, superheater, and economiser, of 80 per cent.

The turbine-room at present contains five turbo-generators each of 12,000 k.v.a., and six steam compressors each having an input of 3,500 kw.; three more steam compressors, each taking 7,030 kw., are also being installed. The turbines are of the A.E.G. Curtis horizontal type, having one high-pressure wheel with three rims of blades. The admission pressure at the intake nozzles is brought down from 220lbs. at a temperature of 300°-350° C. to about 20lbs. with a superheat of about 20° C. In the low-pressure portion of the turbine, the steam is expanded through 12 stages. Both hand and motor regulation of the speed are arranged for.

The stators of each of the 6-pole generators are bar wound, having one bar per slot. The machines running at 1,000 revs. per minute produce 50-cycle 3-phase energy at 5,000 volts, which is stepped up to either 10,000, 20,000, or 40,000 volts, by transformers directly connected with the stator terminals. Substantial clamping is employed on the end windings of the stator so as to withstand short circuits. The rotor coils are lined with metal casings before being attached to the rotor by dovetailed grooves and wedges. The rotor carries a ventilating fan at each end. Each turbine set is provided with a direct-driven exciter, while a stand-by supply is also available from a motor-generator and battery.

The condensers have a cooling surface of 17,750 sq. ft.; each set has a centrifugal circulating pump of about 663,000 gallons per hour capacity, and a centrifugal air pump, both connected on one shaft and driven direct by a steam turbine. The exhaust from the auxiliary turbine is taken to the middle stage of the main turbine, where the remaining energy in the steam is utilised down to the vacuum of the condenser. With the exception of certain electrically driven bearing-cooling pumps, all auxiliaries are turbine driven.

The generator transformers are connected by cables to their corresponding generators, and are each of 12,000 k.v.a. capacity. Where larger transformers have been required, as for the last two sets at Vereeniging, two transformers for each machine have been installed. The transformers at Rosherville are of the shell type and water cooled, the windings nearest the terminals being specially insulated to withstand between adjacent turns a pressure of 25,000 volts for five minutes. A test pressure of 160,000 volts was applied to the whole of the windings.

The steam turbo-compressors at Rosherville are similar to the motor-driven compressors at Robinson Central, and are each designed to deal with 22,000 cub. ft. of free air per minute, with an outlet pressure of nine atmospheres (absolute). The power required on the shaft is roughly 3,500 kw. In the case of electrically driven sets at Robinson Central, each unit is divided into two halves on separate shafts, each motor having a capacity of about 2,000 k.v.a., and being designed to operate at full load at a leading power factor of 85 per cent. The sets run at 3,000 revs. per minute. The steam-driven compressors are arranged in two sections on the same shaft with an intercooler between them. The cooling water required for the jackets of the compressor and intercooler amounts to about 40,000 galls per hour. The air leaves the compressor at a temperature of about 70° C. Between the compressor and the pipe line an automatic non-return valve is fitted, which allows a compressor to drop out to atmosphere when its pressure falls below that of the air system. By the use of the rotary compressors the air entering the pipe system is kept entirely free from oil and other impurities liable to be introduced into the air system when piston compressors are employed. The speed regulation of the steam turbo-compressors is automatically controlled by the pressure in the air pipes. The regulation of the electrically driven compressors at Robinson Central is effected by throttling the intake.

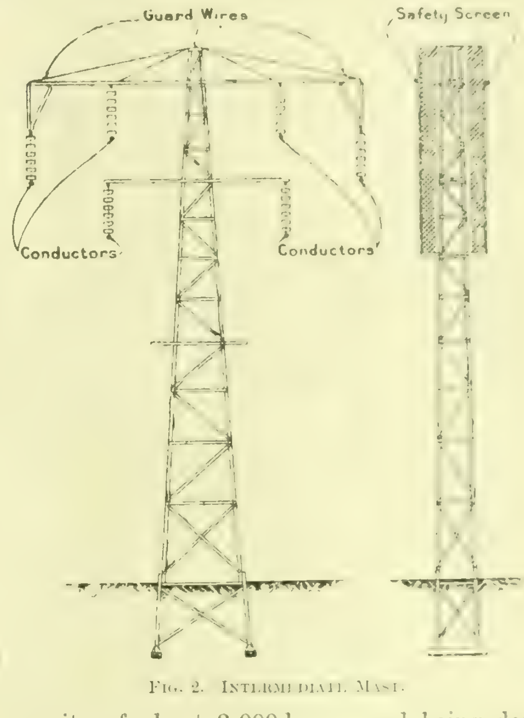


FIG. 2. INTERMEDIATE MAST.

The switch gear is laid out in a building at the southern end of the station, and the step-up transformers are in cubicles arranged along the outer side of the switch-house. The last-mentioned is constructed with four floors; the upper floor contains the lightning-arrester gear, the third floor the bus-bars, the second floor the 40,000 and 20,000-volt oil switches, whilst the lower floor is occupied with cable-ways and pipe passages. Duplicate bus-bars are installed for both the 10,000 and 20,000-volt systems, the various oil switches being provided with knife selector switches to connect to either

busbar. The 40,000 and 20,000 volt systems are connected together through coupling transformers. The switches consist of three single-phase coupled switches operated from a remote control board.

Since the Rosherville station came into commercial service, troubles have been experienced owing to failures of switches on short-circuit. When the Brakpan and Simmerpan stations were started to supply the 40,000 volt transmission and also the 10,000-volt local lines, their total capacity was 24,000 kw., and no trouble was experienced when a short-circuit occurred on the system. When, by the addition of Rosherville, the system grew to 60,000 and 70,000 kw. capacity, switch breakdowns occurred, conclusively proving that no apparatus was available which could be relied upon to interrupt the immense rush of current occurring on short-circuit. Some serious line interruptions have in the past been caused by the wilful throwing of bare wires over the lines. When this form of short-circuit has occurred near a power station, apparatus has usually been lost.

Dynamos running at a high speed have a low internal reactance. The step-down transformers in the present case were designed with a low reactance to give a good regulation, so that probably the total reactance in circuit on a short-circuit

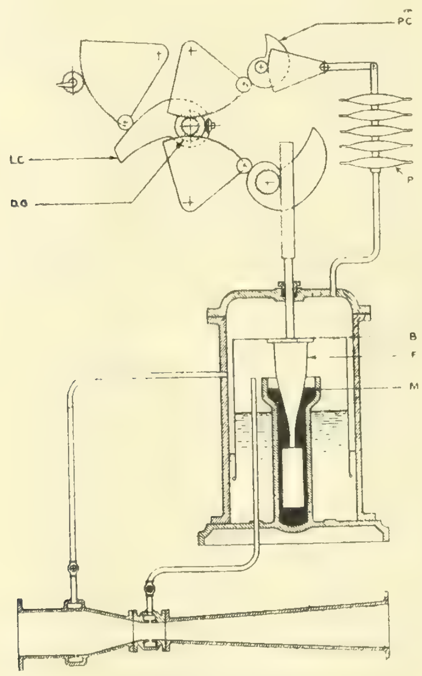


Fig. 3.—Air Meter.

was about 7 or 8 per cent. The momentary rush of energy on short-circuit could therefore reach the tremendous proportions of 500,000-700,000 kw. No oil switch as at present designed could interrupt this rush of power unassisted. The intensely hot gases formed by the arc after rising through the oil come into contact with the air and cause an explosion, which more often than not is productive of a switch failure. Many methods have been tried at Niagara, Chicago, and other places, and it has become generally recognised that it is necessary to insert additional reactances in order to limit the rush of energy on short-circuit. In certain cases this precaution has proved entirely satisfactory. In others additional methods for assisting the oil switch have been necessary, such as (i.) sectionalising the system on to separate busbars and limiting the amount of machinery that would be affected by one short-circuit; (ii.) the placing of two switches in series timed so that one opens first and inserts a non-inductive resistance, the circuit being actually broken by the second switch; (iii.) the use of a special type of switch having two moving systems, one of which first introduces reactances, and the other then breaks the circuit.

These methods have been tried on the Rand. The earthing of the neutral through a resistance has proved most valuable, as more than 90 per cent. of the faults start as faults to earth. At Rosherville and Vereeniging reactances having a value of about 6 per cent. have been installed between the dynamos and the step-up transformers. The latest practice is to design both generators and transformers required for power service with large internal reactances. At Vereeniging and at the Rand end of the 80,000-volt line two systems of switching have been installed. On the first two Vereeniging machines two switches employed are in series, one introducing a non-inductive resistance; while on the last two machines, both of which have not yet been put into service, a two-movement reactance switch is being installed. This switch is constructed on the lines of an oil-break switch, but is provided with a second pair of contacts for the final break. The separation of the first pair of contacts introduces two reactances placed centrally one on each terminal bushing inside the oil tank, and the second pair of contacts finally breaks the circuit. At some early date the system will also be sectionalised in order to reduce the rush of power on short-circuit, and in doing so reactances of relatively large value can be inserted between sections in those cases where it is not economical to separate adjacent sections permanently. This problem of switch gear for dealing with enormous rushes of power has proved one of the most difficult that has been encountered so far on the Rand and also in America. It has not yet been finally solved.

Technical Returns.—The supervision of the power stations by the administration is based on weekly balance-sheets from each station, showing the efficiency of each process. The form in which these returns are made is based upon the underlying idea of energy, and all energy in whatever form it appears, whether as heat in the coal or in the steam, is expressed in the electrical engineer's unit, *i.e.*, the kilowatt-hour. The energy value of each pound of coal, usually expressed in British thermal units, is converted to kilowatt-hours by multiplying by 0·000293; thus a coal of 11,300 B.Th.U. per pound has a value of 3·3 kw.-hours per pound.

The product of the number of pounds of coal burnt per kilowatt-hour and the energy value per pound gives the coal energy required for each unit of electrical energy sent out; and the reciprocal of this multiplied by 100 gives the overall efficiency of the station. Thus, taking an average figure for Rosherville of 2½lbs. of coal per unit sent out, and 3·3 kw.-hours (11,300 B.Th.U.) for the heat value of the coal per pound, the overall efficiency is 12 per cent. In a similar manner the energy in the steam is calculated in kilowatt-hours from Mollier's steam tables. The boiler efficiency is the ratio of the kilowatt-hours in the steam (less the energy supplied from the hotwell) to the kilowatt-hours in the coal. The efficiency of the engine-room plant is expressed as the ratio of 1 kw.-hour of electrical output to the kilowatt-hours of available energy in the steam, *i.e.*, to the total energy of the steam less the heat rejected to the condensers. The ratio of the available energy in the steam to the total energy in the steam gives a measure of the efficiency of the condensing process.

The Compressed-air System of the Rand Mines Power Supply Company.—The compressed air required for the various mines had to be supplied at an average pressure of 100lbs. per square inch, delivered on the property of each of the consumers. The initial demand involved a maximum load of about 30,000 kw., but this has since been nearly doubled. All the advantages of centralisation of power production, such as the use of large units, saving in capital and operating, diversity amongst the mines, spare plant, &c., apply to this form of power supply. The system of centralising the compressor plant and transmitting by pipes was therefore adopted. The distance between the two extreme mines served by the air-pipe system is approximately 14 miles. The total length of pipe laid is 20 miles, varying in diameter from 24in. to 9in.

The problems attaching to this method of power distribution had not previously been considered on so large a scale, and in view of the small amount of data and experience available the successful installation and operation of this air system are of some interest. After a consideration of a number of possible alternatives for giving this supply both economically and reliably, it was finally decided to install steam-driven rotary compressors at Rosherville Dam, and to erect an electrically-driven compressor station at Robinson Central Deep, a point six miles to the west, where a supply of water was

available for cooling purposes, the two stations operating in parallel on a common trunk pipe system. The additional cost of two stations as compared with one was found to be more than offset by the saving in the cost of air mains and by the beneficial influence on the power factor of the compressor motors at Robinson Central; these motors were designed to operate at a leading power factor of 85 per cent. at full load. Six steam-driven rotary compressors have consequently been installed at Rosherville, and six similar compressors, electrically-driven, at Robinson Central, each compressor being rated at about 3,500 kw. input. These machines are the largest compressors yet constructed, 1,250 kw. capacity representing the construction limit previously reached. To meet the increase in the demand three additional steam compressors, each rated at 7,000 kw., are under construction.

Before electrification the mines obtained their compressed air supply by reciprocating steam-driven compressors at each mine. The agreement defined that the consumers should pay the same price for any given quantity of compressed air as they would have paid for the indicated steam energy necessary to enable their reciprocating compressors to produce this quantity of air, assuming that they bought this steam energy at the same rate per kilowatt-hour as they were paying for electrical energy for other purposes. This involved measuring the quantity of compressed air which could be delivered for each 1·34 i.h.p.-hour (1 kw.-hour) developed in the cylinders of the consumers' reciprocating compressors. The weighted average overall efficiency of the reciprocating mine compressors was found to be 64·1 per cent., so that the commercial air unit was fixed at 0·641 of the quantity of air which would be compressed isothermally by the expenditure of 1 kw.-hour.

The tests of the six compressors on the mines had to be conducted in South Africa, and as no meter existed then, and the usual methods of testing compressors were far from accurate, new methods had to be devised to determinate a unit on which the purchase of power worth £250,000 a year for 20 years was to be based. The measurement of the discharge from the compressors through orifices was decided upon with the idea that the performance of the compressors could be recorded against these orifices. A master meter was designed by the Rand Mines, Ltd., and constructed by Messrs. Fraser and Chalmers, which was ultimately erected in an air-testing station at the Ferreira Deep Gold Mine. This meter is a 3-crank displacement meter of a very large size, and has been specially designed so that any clearances, leakages, &c., which would reduce the accuracy, have been made a minimum. Being a displacement meter, a direct measurement of the air is obtained without the introduction of empirical formulæ. Though a large machine, standing about 10ft. high and 15ft. long, it is so sensitive that it gives consistent and accurate results for a flow of air through an orifice $\frac{1}{16}$in. diam. The orifices used in the compressor tests were compared with this master meter and their coefficients determined.

Subsequently an opportunity presented itself of comparing the work done in air measurement in South Africa with the collateral work done in England when developing the air meters. When the results were compared it was found that there was not more than $\frac{1}{2}$ per cent. difference between the two. The work of testing the six sample compressors occupied 12 months.

Air Meters.—A general description of the principle of the Venturi meter adopted may be of interest. It has been agreed that the mean annual temperature on the Rand, 60° Fah., should be taken throughout, and similarly also the mean annual atmospheric pressure of 12·086lbs. per square inch, was adopted. Measurement of the weight of air by means of a Venturi tube is found by taking the drop in pressure across the throat, and the temperature and pressure at the point of supply, in accordance with the formula $W = K (P H / T_1)^{\frac{1}{2}}$; where K is a constant, H is the pressure drop across the throat, and P and T_1 are the pressure and temperature respectively at the point of supply.

The recording mechanism has to multiply continuously two variables, one dependent upon the weight of air passing, and the other on a function of the pressure of supply. The weight of air is measured by the drop of pressure across a Venturi tube (T in Fig. 3) fixed in the pipe line. In the meter adopted the Venturi head is measured by means of an inverted bell (B) sealed by oil (O), the movement of which is controlled by a specially-shaped float (F) that enters and leaves a mercury bath (M). This float is so shaped that the displacement of the bell corresponding to any Venturi head is proportional to the logarithm of the number of pounds of air passing at a given pressure and temperature. The arrangement is sensitive to a Venturi head of less than one 10,000th of a pound per square inch, and it will measure a Venturi head up to 0·85lb. per square inch.

The pressure of delivery is measured by steel diaphragms (P), and a displacement proportional to the logarithm of the required pressure function is obtained from them by means of a cam (P C). These two displacements, each proportional to the logarithm of one of the variables to be measured, are added together by means of a differential gear (D G), similar on a small scale to that used on the back axle of a motor-car. This combined displacement is finally converted by means of a logarithmic cam (L C) into a displacement proportional to the power (kilowatts) in the pounds of air being delivered.

The meter is provided with direct reading recording dials which are capable of being connected with a clock-driven shaft running at one revolution every two minutes. The displacement proportional to the kilowatts regulates the length of time that the train remains in gear during each revolution of the clock-driven shaft by means of a clutch. To avoid winding, the clock is driven by a small constant-speed air turbine. The

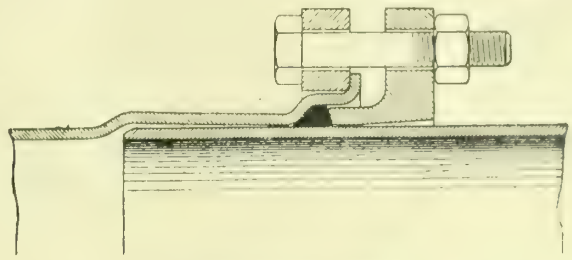


FIG. 4. AIR PIPE JOINT.

guaranteed accuracy which has been maintained in operation is as follows: Full load, 1·5 per cent.; half load, 1·75 per cent.; one-tenth load, 2·25 per cent. The meters were constructed by Messrs. George Kent, Ltd., of London.

Operation of Air System.—The results of the operation of the air system have been observed over the 20 months since the supply was first put into commercial use, and have been very satisfactory. Experience has shown that there is no difficulty in parallel running with the compressors installed, and that the engineers in charge are able to operate the compressors satisfactorily. It has been found that of the air units sent out 95 per cent. have been recorded at the consumers' meters, 3 per cent. have been lost in transmission, and 2 per cent. are unaccounted for. The monthly air load factor is at present 50 per cent. The drop in pressure to the various mines varies according to the distance and the size of the pipe, but with the pipe system laid down the average pressure drop is not more than 6lbs. Careful observations are being taken of the condition of the pipes, and up to the present there is no reason to suppose that much deterioration will take place. Of 4,000 joints which are designed to allow for contraction and expansion only those within a radius of half a mile from the stations, where the temperature variations are greatest, have required attention. The joint used in the pipe line is of the spigot and socket type, the jointing material consisting of an india-rubber ring, which is made tight by a gland as shown in Fig. 4.

Consumers' Sub-stations.—The electrical supply at [illegible] volts and 550 volts to the consumers' premises is effected from step-down transformer stations, which are built by the consumers, but are equipped with switch gear and transformers by the power company. There are 60 of these consumers' sub-stations connected to one system, and their individual capacity varies from 10,000 k.v.a. to 2,000 k.v.a., the normal size being 5,000 k.v.a. The standard sizes of consumers' transformers are 1,000, [illegible], and [illegible] k.v.a., designed with the primary windings arranged for either 20,000 or 10,000 volts. A temperature rise of 40° C. is allowed above an air

temperature of 40° C. The windings near the outgoing terminals will stand a pressure of 15,000 volts between adjacent turns. The high-tension windings are tested to the secondary windings and core with a pressure of 40,000 volts, and the insulators with 60,000 volts.

The transformers are exported filled with oil, thereby reducing the cost of transport and dispensing with the necessity of drying out after erection. In order to allow for the expansion and contraction of the oil each transformer tank is connected with a second smaller tank fixed on the wall of the sub-station. This expansion tank is fitted with a vertical vent pipe, so that only a small surface of oil is in contact with the air, and by this means sludging is prevented. Each sub-station chamber has a short stack, which induces a natural draught and provides effectual ventilation. Double busbars are provided for each voltage. The high tension and low-tension switch gear in each sub-station is arranged in different chambers with a central operating passage between containing no "live" material. The "live" chambers are locked, and stringent regulations as to the possession of the keys ensure that no authorised person can obtain access; in no case is one man allowed to enter alone. The total capacity of the transformers in operation, including generator transformers and coupling transformers, is unusually large, amounting at the present time to 450,000 k.v.a.; but this will be increased to 508,600 k.v.a. when the transformers delivered and on order are brought into commission.

BAR CHUCKING MECHANISM FOR MACHINE TOOLS.

We illustrate herewith two arrangements of chucking mechanism for lathes and other machine tools, the invention of Messrs. H. W. Ward & Co., Ltd, Lionel Street, Birmingham. In the arrangement shown in Fig. 1, two longitudinal sleeves are employed, one of which A is fixed, whilst the second one B is longitudinally movable. At the rear of the headstock is a member C, which is keyed upon the fixed sleeve A, but slidable along same under the influence of the controller marked D. In this member C is a pair of helical slots E, indicated by dotted lines, and in these slots are lugs F, carried by a sleeve G, which is adjustably connected to an abutment H. Within the sleeve G is a liner piece J, having at its rear end face a plurality of cam surfaces K, which co-act with corresponding cam surfaces and a member L secured to the fixed sleeve A. When the member C moves longitudinally it gives a partial rotation to the sleeve G, and thus to the member J,

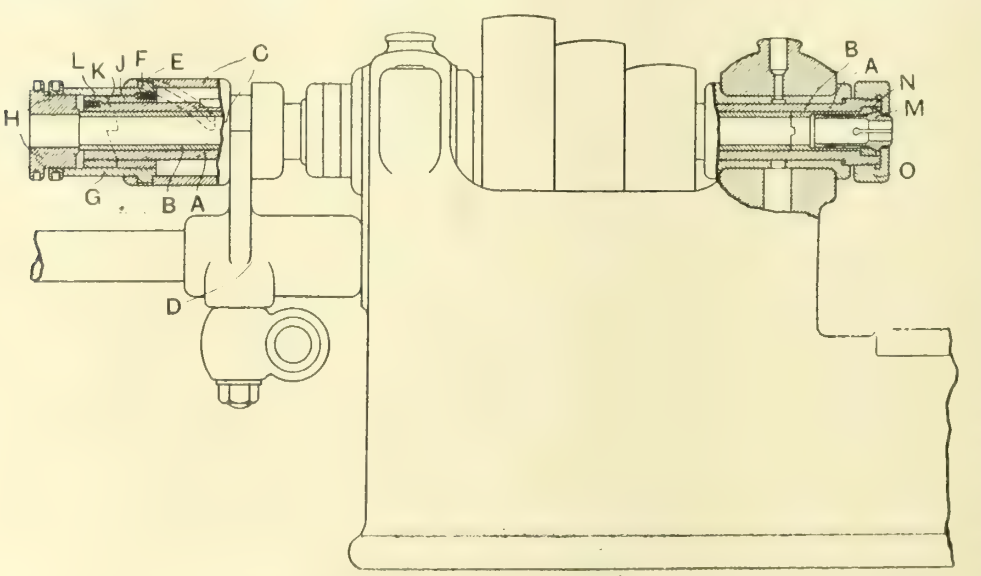


FIG. 1. BAR CHUCKING MECHANISM.

this member being moved endwise under the influence of the cam faces K, and as the part J is connected to the sleeve G, it is obvious that they will both move longitudinally together, and being connected to the part H this will also move longitudinally. The part H abuts against the rear end of the sleeve B, so that the longitudinal movement of the former will be imparted to the latter to close the collet. The collet M has a tapered shoulder portion N, which fits within a corresponding opening in the sleeve B, whilst the collet abuts against a cap O, carried by the fixed sleeve A, and it will thus be obvious that when the sleeve B moves longitudinally its

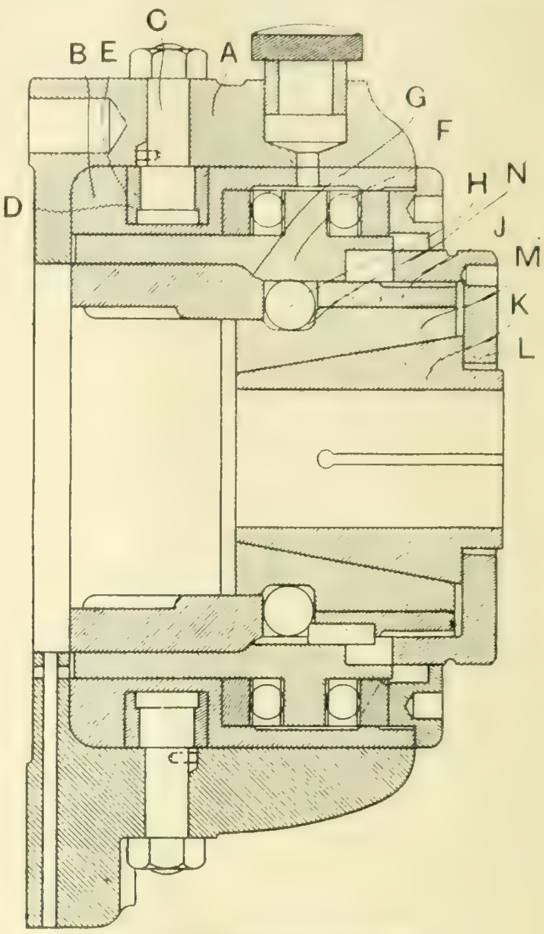


FIG. 2.—BAR CHUCKING MECHANISM.

tapered mouth co-acting with the incline M on the split collet will cause the collet to contact about the work, without imparting to it any longitudinal movement.

In the arrangement shown in Fig. 2 there is a shell A which carries a controlling lever and pinion, which engages corresponding teeth in a rotatable member B. The casing A has projecting studs C carrying anti-friction rollers D, which engage helical slots E in the rotatable sleeve B, so arranged that when this sleeve is partially rotated a longitudinal movement is also imparted to it. Movable with the sleeve B is a second sleeve F, having an incline G, which engages with a series of balls H carried in radial holes in a sleeve J, this sleeve being fixed against longitudinal movement. The collet K abuts against a cap L, secured to part J, and between these two parts is a sliding member M, which co-acts with the inclined portion of the collet. The member M has an annular recess N, which receives the innermost portion of the balls, being so arranged that when the sleeve F is moved to the left, *i.e.*, to the position illustrated, the inclined portion G forces the steel balls inwardly in a radial direction when they abut against the hole in the fixed sleeve J, and the annular recess in the sleeve M, the latter being so arranged that when the steel balls are forced inwardly a longitudinal movement is imparted to it, and obviously a longitudinal movement of the part M will compress the collet. It will be seen that a movement in the opposite direction will uncover the steel balls, when the collet will expand under the influence of its own spring pressure moving the sleeve M endwise.

PROPORTIONS OF THE MOULD TO MAKE SOUND INGOTS.*

BY EMIL GATHMANN.

IN presenting this paper I will attempt to answer certain questions proposed at this meeting, and describe and illustrate methods of producing sound steel in an economical and hence commercial manner, which are adaptable to the production of practically all steel manufactures, by readily-effected rational changes in the methods of casting, cooling, and subsequent handling of the ingots.

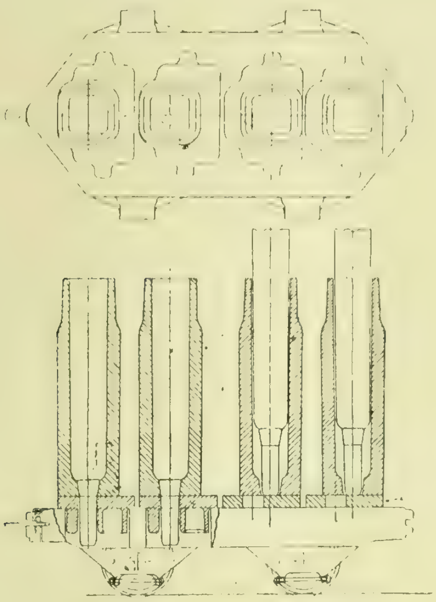


FIG. 1.—GATHMANN INGOT MOULD AND STOOL ON CAR.

In some of the high-grade mills of America, where it is essential to obtain perfectly sound billets or blooms, it is the practice to discard from 35 to 40 per cent. of the crop or pipe end, and even with this excessive discard, secondary pipe or shrinkage cavities are frequently discovered during subsequent working of the blooms and billets into their various manufactured products. The usual discard of from 10 to 20 per cent. from the crop end of the ingot, which is customary with the form of ingot and method of solidifying generally employed, certainly does not give the slightest assurance of the saleable product being physically sound or chemically homogeneous.

Physically sound steel, as I would classify it, must be free from blowholes as well as pipe. The line of demarcation between harmless and harmful blowholes is exceedingly difficult to define. It is certainly the better and safer practice to eliminate blowholes from the saleable portion of the ingots, and to form a well-defined shrinkage cavity or pipe at the upper crop-end of the ingot. The higher grades of steel are all piping steels. Is not their superior physical quality due to this fact as well as to their better chemical composition? Such is the case, in my opinion. Steel has frequently been chemically excellent in the furnace or ladle, but of very poor or indifferent quality in the ingot and in the subsequent manufactured shapes.

It has been my experience that the freezing or solidifying of an ingot which has been practically deoxidised or, as it is termed, "killed" in the mould, depends entirely upon the shape of the horizontal cross-section of the ingot at its various planes from top to bottom, and also upon the thickness and consequent heat-absorptive power of various parts of the mould walls.

Specifically, the new method here described employs a metallic mould constructed to accelerate the cooling of the lower or greater portion of the molten mass of the teemed ingot (approximately from 80 to 85 per cent.) and retard the cooling of the uppermost portion of the ingot, thus causing the upper portion to remain liquid longer and to act as a feeder. The upper portion does not actually remain liquid much longer than in the usual practice for ingots of similar cross sectional area, but as the cooling of the lower portion is greatly hastened a differential in cooling is obtained, which is really what is to be desired. Similar results have been obtained by employing firebrick, or heating of the upper part of the ingot by coke, charcoal, or the like; but these methods usually off-set any saving in a reduction of the crop ends.

In ordinary "big-end up" practice, where sufficient taper or differential in distance from the vertical axis to the surface of the ingot is given to accomplish any notable reduction in depth of piping, the actual cross-sectional area of the lower part of the ingot is much less than that at the upper part; hence the depth of pipe is not the true index of the actual volume or weight of cropping necessary to obtain physically sound steel.

One of the advantages of the system described is that it is possible to obtain a practically uniform cross-sectional area at top and bottom of the ingot and still obtain the benefits of the big-end-up type of mould. Lifting of segregation is generally conceded to follow the reduction of pipe, and where the pipe is lifted the steel below undoubtedly becomes more homogeneous and freer from segregation.

For open-hearth practice with the big-end-up ingot, one of the greatest difficulties has been to devise a method of stripping and handling the ingots. I have worked out a method which will accomplish this result, and not interfere with the prevailing administrative practice or reduce the tonnage productions; in fact, if anything, these new methods of stripping should increase the tonnage, as well as ensure the sound steel with a greatly reduced cropping.

Fig. 1 shows the Gathmann ingot mould and stool on a car or buggy after teeming. The big-end-up mould will require a special type of stool to avoid such difficulties as might ordinarily be experienced in stripping, due to fins forming at the base of ingot and locking it to the mould. A downwardly tapered plug seals the base of the mould and projects through the stool. When the teeming is finished the metal, by reason of the wedge-like taper at the lower portion of the ingot, is forced into virtual contact with the walls of the mould, which, due to their thickness, rapidly absorb the

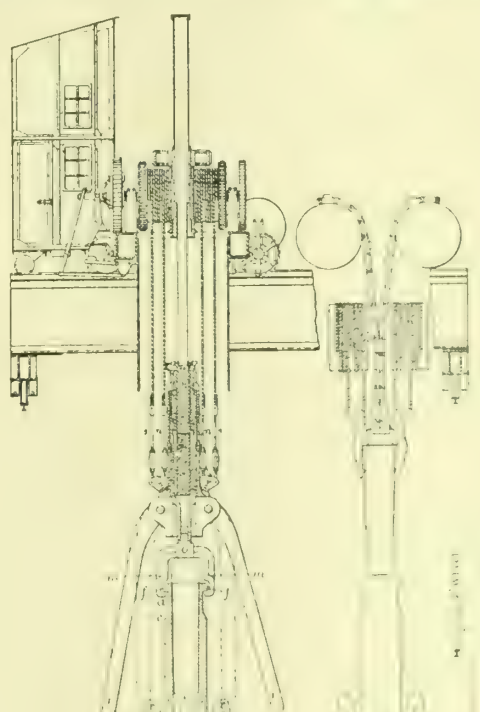


FIG. 2.—STRIPPER ARRANGED FOR BIG-END-UP MOULDS.

heat of the ingot. A slight differential or reverse taper of the ingot cavity is made 15 to 20 per cent. from the top of the mould. The ingot in shrinking will automatically provide an air space at this portion, thus breaking the contact of the ingot with the mould walls, and retarding the flow or loss of heat from this portion of the ingot.

* Abstract of paper read before the American Institute of Mining Engineers.

Fig. 2 shows a stripper of well-known construction, with some details changed to suit the stripping of the big-end-up mould. The usual plunger is provided with a yoke, whereby the lifting lugs on the mould may be engaged. The plunger may then be raised or lowered, thus raising or lowering the mould, and in case of the ingot sticking in the mould upon lowering, the yoke is forced downward on the mould which rests on the combined sealing and stripping plug; the ingot is thus protected above the upper part of the mould, or rather the mould is lowered down, exposing the upper part of the ingot. If a "sticker" is encountered, the weight of the thrust from the yoke on the upper portion of mould is taken up by the hanging arms, which engage the lugs on the stool. The usual soaking-pit crane is employed to remove the ingot entirely after it is exposed above the mould walls.

Fig. 3 shows a slab ingot mould designed for plate or sheet mills desiring to roll directly from the ingots. This ingot is made similar to the crucible-steel ingots, with uniform

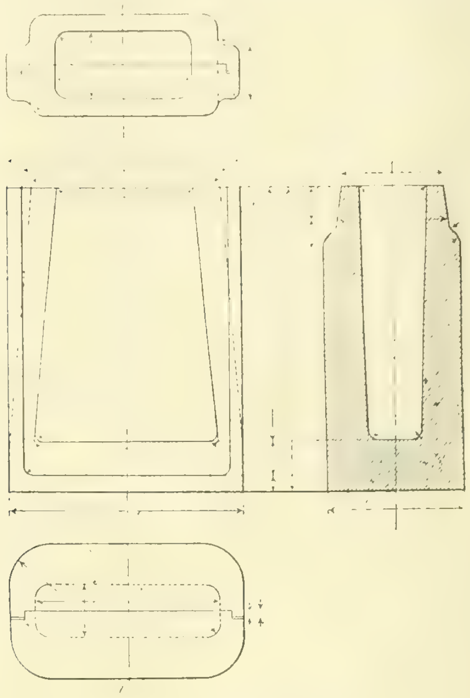


Fig. 3.—Design of Slab Ingot Mould.

cross-area at top and bottom so as to obtain equal width from finished plates or sheets. The ingot may be designed of approximately the following general dimensions: 10in. by 20in. at the upper portion and 7in. by 26in. at the lower portion. The nearest distance from the vertical central axis of ingot to the surface of the same would thus be 5in. at the top of the ingot, and but 3·5in. at the lower part, with approximate progressive dimensions intermediate. This ingot is cast in a similar design of mould to that previously described, wherein the cooling is greatly accelerated by the absorptive action of the heavy mould walls. This mould is necessarily made in two parts, and held together with clamps in order to allow ready stripping of the ingot.

The general practice, as outlined, reduces the pipe in the deoxidised or killed steel, so that with an average discard of 12 per cent. sound metal will be obtained. Segregation will undoubtedly be disposed of in direct ratio to the lifting of the pipe. The stripping apparatus and bottom-sealing stool make practicable the use of the big-end-up ingot without complications in removing the ingot. The system, which is patented, is not in an experimental stage, as many tons of steel are daily being cast in both open-hearth and crucible plants in accordance with it.

The features which require special mention are: (1) No increase in cost of manufacture. (2) Simplicity in (*a*) construction and (*b*) operation. (3) No radical interference with present plant practice. (4) No skilled labour or supervision and attention required beyond such as may at present prevail in any mill. (5) It reduces the piping and provides physically sound steel by the accompanying reduction of segregation.

SOME EFFECTS OF SUPERHEATING AND FEED-WATER HEATING ON LOCOMOTIVE WORKING.*

BY F. H. TREVITHICK AND P. J. COWAN.

(*Continued from page 335.*)

Another test is interesting, though made with a lighter class of engine, fitted with a type of installation since greatly improved upon. These trials covered the service working of the Upper Egypt expresses for a period of over two months, extending to 88,480 train-miles, run by 16 heater and 18 non-heater engines. The trains are worked in three sections—Cairo-Minieh (154 miles), Minieh-Sohag (138 miles), Sohag-Luxor (128 miles). Coaling was done at Cairo and Sohag only, from the latter engines working both north and south. Engines were given sealed sacks of coal sufficient for both the out and home trips. The distance in Section I. (Cairo-Minieh) is accomplished with three intermediate stops, in Section II. (Minieh-Sohag) with 11 stops and 10 slacks for staff changing, and in Section III. (Sohag-Luxor) with 13 stops and seven slacks for staff changing. The results are given in Tables VI. and VII. Train loads were kept uniform throughout the test, an extra coach being added at intervals, until the capacity of the non-heater engines was exceeded.

Table VI.—*Upper Egypt Express Trials. Average Results for separate Sections and for all Sections together.*

Sections	I.		II.		III.		I., II., & III.	
No. of engines with or without heaters	3 with	6 without	5 with	5 without	8 with	7 without	16 with	18 without
Aggregate train mileage	18,172	18,172	13,524	13,524	12,544	12,544	44,240	44,240
Average tare behind tender ..	302·6	301·6	300·6	301·8	300·5	302	302·3	301·8
Coal consumption Average lb. per mile	29·6	37·8	32·5	43·0	33·6	44·8	31·6	41·4
Economy in favour of heater engines, per cent.	21·7		24·4		25·0		23·6	
Average lb. per ton-mile	0·0977	0·1255	0·1082	0·1427	0·1110	0·1490	0·1047	0·1373
Economy in favour of heater engines, per cent.	22·1		24·1		25·5		23·7	

The coal economy per ton-mile varied in these trials for the heater engines from 22·1 per cent. in Section I. to 25·5 per cent. in Section III., with an average of 23·7 per cent. for the whole test. These tables are reproduced, however, to show the effect which load and stops have upon the economy. On light trains in Section I., with three stops only, the non-heater engines took 36·7lbs. of coal per mile and the heater engines took 28·4lbs. For similar trains, in Section III., with 13 stops and seven slacks, the consumptions were 42·9lbs. and 33·5lbs. respectively, the heater engine taking 5·1lbs. extra per mile, but the non-heater 6·2lbs. extra. For the heavy trains the difference is increased. In Section I., for trains of 337 tons tare behind the tender, the non-heater engines took 38·4lbs.; but in Section III. they took 47·1lbs., a difference of 8·7lbs., while the heater engines took 30·6lbs. for Section I., and only 34·4lbs. for Section III., a difference of 3·8lbs. In an extension of this test, in Section I., the heater engines were able to handle satisfactorily trains of a weight which completely outclassed the non-heater engines, it being quite impossible to keep time with the latter.

In regular service, engines fitted with the apparatus, Type B, Appendix I., have confirmed the tests. Engines of the 706 type have run consistently on an extremely low consumption, in complete accord with the test results. Direct comparison with sister non-heater engines is, unfortunately, no longer possible in this case, since the use of the non-heater engines on the heaviest schedules had to be abandoned, owing to the time they lost. For two months for which the records were recently taken out, Engines Nos. 706 and 714 averaged respectively trains of 349·3 and 345·5 tare tons behind the tender (loads which the sister non-heater engines cannot touch on this

* Paper read before the Institution of Mechanical Engineers, March 14th, 1913

timing) at a coal consumption per ton-mile of 0·1005lb., including lighting up, &c., and are very consistent over long periods. This consumption is identical with that of No. 706 during the trials mentioned above. The trial results for the Upper Egypt "612" class are likewise supported by Table VIII. taken from the registers.

TABLE VII.—*Upper Egypt Express Trials; Average Results for Sections and Train Loads.*

Nominal train load. Tons tare.	Type of Engines with (+) or without (−) heaters.	Actual average load. Ton tare.	Coal consumption. Average lb. per mile.	Economy in favour of heaters.	Average lb. per ton-mile.	Economy in favour of heaters.
		Section I.		Per cent.		Per cent.
260	+	262·8	28·4	22·6	0·1082	23·4
	−	259·5	36·7		0·1414	
308	+	306·9	30·0	22·0	0·0977	21·8
	−	308·2	38·5		0·1250	
337	+	339·0	30·6	20·3	0·0904	20·5
	−	337·3	38·4		0·1138	
362	+	362·3	31·6	23·3	0·0874	23·2
	−	362·1	41·2		0·1139	
		Section II.				
260	+	262·4	32·5	22·8	0·1239	23·0
	−	261·7	42·1		0·1611	
308	+	307·8	32·3	24·2	0·1048	24·4
	−	306·4	42·5		0·1388	
337	+	331·6	32·9	25·7	0·0994	24·4
	−	337·3	44·3		0·1315	
		Section III.				
260	+	265·7	33·5	21·9	0·1261	22·7
	−	263·0	42·9		0·1633	
308	+	307·5	33·2	24·5	0·1080	24·7
	−	307·0	44·0		0·1436	
337	+	337·0	34·4	26·9	0·1020	27·2
	−	336·0	47·1		0·1403	

(3) **High Degree Feed-heating and High Degree Superheating.** — Owing to the lack of sufficient data it is not proposed to go at length into calculations regarding this combination. It is not known how far the curve *d*, Fig. 2, agrees with the performance of a combined high degree superheater and boiler. Further, when high degree feed-heating is combined with superheating, the superheat is reduced, but to what extent is yet uncertain. Also, superheater engines are

TABLE VIII.—*Service Working for Upper Egypt Engines "612" Class.*

		Average tare. Load tons.	Coal per ton-mile.	Economy in favour of heaters.
				Per cent.
1909	16 Engines before fitting with heaters.	240·2	0·1692	29
1910	Same Engines after fitting	263·5	0·1201	26·1
1909-10	19 Engines not fitted	246·4	0·1626	
9 months 1910	16 Engines fitted with heaters.	266·6	0·1194	23·7
9 months 1910	19 Engines not fitted	246·4	0·1565	23·7

commonly fitted with piston valves, to which part of their performance should rightly be credited, instead of the improvement being wholly imputed to the superheating system.

If, however, superheating to 200° Fah. with feed-heating to 290° Fah. be considered, using the curve *d*, Fig. 2, as the basis, the following results are shown: Fig. 9 shows for this superheat 21·15 per cent. steam economy. The original 542·57lbs. of engine steam would therefore be reduced to 427·82lbs., and the heat needed would be 427·82 (1,307-33·07) = 545,010 B.Th.U. The pump takes saturated steam representing (427·82 × 0·022 × 1,164·63) = 10,960 B.Th.U., the total being 555,970. Subdividing this among the pump heater, the main exhaust heaters, the smokebox heater, and the superheater and boiler, it is found that 457,050 B.Th.U. have to be provided by the superheater and boiler. The point on the curve *d* corresponding with this represents a rate of firing of 49·1lbs. per square foot, as against 80, or a saving of 38·64 per cent. The loss in the waste gases has been reduced 57 per cent., and that by unburnt coal 75 per cent. These large savings seem to be substantiated in practice.

A smoke-tube superheater, giving 200° Fah. superheat, may not be considered to be representative of actual practice, but the figure is chosen because of the unavoidable fall of superheat already referred to. With the lessened boiler duty the intensity of draught is reduced, and as, for a wide range, superheat varies approximately as the draught, a drop on conversion is natural.

On the Egyptian State Railways an engine, No. 712, giving about 200-220° Fah. superheat before conversion, gave after the addition of the feed-water heaters (see Type C, Appendix I.) superheat of about 150° Fah. Nevertheless the results proved very satisfactory. For reasons identical with those previously stated, this engine could not be tested at its best loads against sister non-heater engines. A trial attempted had to be abandoned. Engine No. 712 was therefore run against the heater Engines Nos. 706 and 714, and, compared with them, with average tare loads behind the tender of 346·8 tons, showed a consumption of only 27·7lbs. per mile or 0·0798lb. per ton-mile: this is an economy of 20·0 per cent. over the Type B heater Engines Nos. 706 and 714. In the 1911 trials Engine No. 706 worked at exactly the same consumption as during this latter period, and the consumption of Engine No. 712, fitted with the high degree feed and high superheat combination, may, in default of more direct means, be compared with that which the non-heater engines then showed. If running at an economical load, Engine No. 712 would thus show an economy of 45 per cent. over sister non-heater engines.

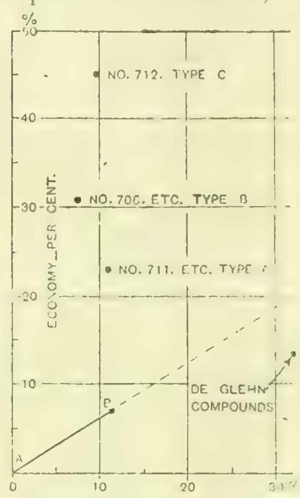


FIG. 15.—RELATION OF ECONOMY OF VARIOUS SYSTEMS TO INCREASE OF WEIGHT.

Direct comparison being impossible on the heavy workings, Engine No. 712 was transferred, for a short time, to a link of lighter trains handled by the non-heater engines. On these trains, however, Engine No. 712 was under-rated, and was not working at its best. It averaged, for trains of 262 tons tare behind tender, 0·0952lb. per ton-mile, against the average for several non-heater engines of 0·1528lb. on trains of 256·5 tons load, or an economy of 37·7 per cent.

The Blast. — In a paper on the efficiency of the method of creating draught by means of the blast, read recently by Mr. H. B. MacFarland of the Atchison, Topeka, and Santa Fe Railway, before the International Railway Fuel Association, the author showed how disproportionate is the effect produced, to the power consumed in maintaining the smokebox vacuum. By ensuring equivalent output with reduced draught, improvement in this direction is secured, and the engine is made freer, in addition to the boiler losses being reduced.

The use, in all the heater systems here dealt with, of part of the cylinder exhaust for feed-heating, is equivalent to an enlargement of the blast-pipe top. The volume of steam driven through the orifice is diminished by over 12 per cent. The diameter of the blast-pipe top is thus virtually increased from the actual 4½in. to a corresponding 4¾in., or from 4¾in. to a corresponding 5in. top. Again, enclosing the blast in a comparatively small chamber, as in the later Egyptian State Railways systems, increases the inducing action and results in comparatively high vacua with a larger nozzle than is used in the standard engine. In the latter a top of 4½in. is used above the netting, and produces in front of the tube-plate a vacuum of about 6in. in normal working. With the high degree superheat system alone, as fitted to Engine No. 712, it was necessary to reduce the top from 4½in. to 4¼in. to obtain a proper vacuum with the reduced quantity of steam then used. Since fitting the feed heaters to this engine (Type C, Appendix I.) the blast-pipe has been enlarged to 4½in., and as part of the exhaust is used for feed heating, it is now

virtually one 4¾in. diam. for about 15 per cent. less steam than passes through the standard top of the ordinary engine. The size to which this 4½in. top actually corresponds is thus about 5in. diam. In the case of the engines with high-degree feed, or with moderate feed-heating and superheating combined, 4¾in. tops are used, the virtual size being, therefore, about 5in. The cylinders benefit greatly by this increased area, and the resultant reduction of back pressure.

With these blast-pipe tops a vacuum of from 6in. to 8in. is obtained in the small blast-chamber. This is reduced by the resistance offered by the heater tubes, and there is a vacuum in the smokebox proper of from 2in. to 3in. compared with 6in. or more in the ordinary engine. This is in accord with the reduced rates of firing necessary, to which a lighter draught corresponds. The natural accompaniment of the softer draught, which allows a thinner and more efficient fire, is higher boiler efficiency with reduced losses in unburnt coal.

The Reduction in the Loss of Unburnt Coal.—The lighter draught just considered results in less loss in unburnt fuel. The Egyptian State Railways engines show progressively, less accumulation of cinders in the smokebox with increased economy. In the non-heater engines the quantity of cinders retained in the smokebox is large, and after a certain length of run practically all cinders, coming through the boiler tubes, except the largest, are probably ultimately forced through the spark arrester mesh and ejected. In one class of passenger engines the smokebox cinders amounted to 2·173lbs. per mile, equivalent to about 1·87lbs. of coal. In sister engines, fitted for moderate feed heating and moderate superheating, the ash collected in the smokebox was only 0·796lb. per mile, equivalent to 0·68lb. of coal. In another class of engine with installations of this type, the ash retained was found to be 1·168lbs. per mile, compared with 3·823lbs. for the non-heater engines, equal to a saving of 2·28lbs. of coal in the smokebox cinders alone, on a consumption of about 47·75lbs. per mile.

The engine with the high-degree superheater only, showed very similar results, while after the addition of the high-degree feed-water heating apparatus, the smokebox cinders collected only amounted to 0·26lb. per mile. Taking into consideration the ash ejected, the actual saving is much greater than these figures indicate. On account of the lighter draught of the heater engines and the obstruction offered by the heater, it is probable that a larger proportion of the cinders drawn through the boiler tubes is retained in the heater engine smokebox, than in that of the non-heater. The total saving is therefore probably very considerable. Absolute deductions, however, are impossible on this point.

The reason why the heater engines show greater economy over the ordinary engines when on stopping trains than when on fast non-stop expresses, is connected with the blast and heater. The smokebox heater offers some resistance to the flow of the gases, and has the effect of damping the heavy pulsations of the blast when the engine is working at or near full gear. The fire is not lifted in the same way. The loss of coal is thus reduced. This becomes marked when loads are heavy and stops frequent, as is shown in Tables VI. and VII.

The Reduction in Smokebox Temperatures.—A reduction in the final temperature of the waste gases naturally results from the use of a smokebox heater. On ordinary engines of the class chiefly dealt with in this paper, the temperature in the smokebox, when on a fast and heavy schedule, will be as high as 800° Fah. with a 6in. smokebox vacuum. The reduced vacuum in the smokebox proper of the heater engines lowers this. In the case of engines Type A, with the high degree feed-heating system, 750° Fah. is a typical smokebox figure, while in passing through the smokebox feed-heater the gases fall further, to about 463° Fah. In the engines Type B, with the moderate feed-heating and moderate superheat, the smokebox temperature is about 730° Fah. and the final temperature 492° Fah. In engine Type C (high feed-heating and high degree superheating) the draught is so light that the smokebox temperature is no more than 668° Fah. at heavy load, and about 634° Fah. on a slightly lighter rating, with final temperatures of 410° Fah. and 389° Fah., respectively, the steam temperature being about 530° Fah.

Economy and Permissible Engine Weight.—It has already been stated that if increase of weight permit, an enlarged boiler will result in a certain degree of economy. Based upon American practice, Dr. Goss has drawn the full line AB, Fig. 15, to show the economy that would be expected when an allowable increase in weight is utilised in enlargement of the boiler capacity of an engine. No great improvement can be looked for by the use of this compared with other methods available. The ordinary standard 4—4—0 engines (695-724 class) of the Egyptian State Railways weigh about 50 tons 15 cwt. without tender. The addition of the Type B heating apparatus, and a trimming slab at the trailing end, involves an increase of about 3·75 tons, that is, about 7·6 per cent., while coal economy amounting to 30 per cent. results from the addition. The Type C combination fitted to Engine No. 712 results in an economy of 45 per cent. for an increase of 4·75 tons, or 9·7 per cent. These weights are comparatively small for the improvement shown. Points representing the installations Types A, B, and C, are shown in Fig. 15, and indicate the superiority of these systems as compared with the mere enlargement of boiler capacity. A further point in the diagram indicates the position of the De Glehn compounds. These engines weigh 67 tons 1 cwt. without the tender. They show an economy over the non-heater four-coupled engines of 13·3 per cent. on an increase of weight of 32 per cent. Judged by the "additional weight" standard these engines show up less well than would, according to Dr. Goss, the simple large-boilered engine, at least as far as continuous work is concerned. However, the heater engines easily have the advantages in this respect, both over the large locomotive, as such, and over heavy compounds of the De Glehn type.

Additional Power.—A diagram complementary to Fig. 15, would be one showing the increase of power, obtained for the increments of weight resulting from the introduction of heater systems. Owing to the impossibility of carrying out tests in great detail on the Egyptian State Railways, the necessary information for this is not available. There is, however, ample evidence that enhanced power results from the use of these systems. Their effect is similar to that of the enlargement of the boiler, viz., to move the "characteristic" outwards on the diagram, so that, at the usual working speeds, additional capacity results in increased draw-bar pull, which may be utilised either in increase of speed or load.

It is frequently advanced that, because at equal loading an economy in coal is shown, at equal rates of firing a proportional increase of power is secured. When an engine shows 20 per cent. economy in coal $\frac{100-80}{100}$, it is held that at equal rates of firing the increase in power should be $\frac{100-80}{80}$ or 25 per cent. Such an example is given in Herr Garbe's book entitled, "The Application of Highly-superheated Steam to Locomotives," and others are constantly met with. The argument is fallacious. While the coal-consumption increases along the steep line a, Fig. 2, the output, upon which power is dependent, only increases along the line d, that is, at a much slower rate.

The effect in the first case of high degree feed-heating (Type A) is to give the boiler of that engine an increase in output of from 531,720 B.Th.U. to 632,000 B.Th.U. at equal consumption. This is equivalent to an increase of 18·8 per cent. compared with the coal economy, at equal loads, of 24 per cent., and with a figure of 31·5 per cent. found by the common method. If general conditions remain unchanged, the increase in available power is greater than 18·8 per cent. If at speeds of about 200 revs. per minute the power absorbed in engine friction be taken, for the sake of an example, to be 20 per cent. of the total, the actual increase in power available for overcoming external resistances, of the feed-heater engine, is not 18·8 per cent., but $\frac{98\cdot8-80}{80}\times100=23\cdot5$ per cent.

In the second case (Type B installation), the increase in boiler output would be from 514,560 B.Th.U. to 632,000 B.Th.U., or 22·8 per cent., equivalent to 28·5 per cent. extra power. In case III. (Type C installation), the combined

boiler and superheater output would be increased from 457,050 B.Th.U. to 632,000 B.Th. U., or 38·2 per cent., equivalent to 47·7 per cent. extra available power. It is here assumed that the heater engine smokeboxes are normal. Actually this is not so. Head resistance must be combined with internal engine resistance when estimating additional power at the draw-bar, or loading.

Additional power has resulted from all the heater systems used on the Egyptian State Railways. Table IX. shows the results for the trials of Engines Nos. 711 (Type A installation) and 695. Table III. also shows that, in ordinary service, Engine No. 711 with heaters has averaged heavier trains than

TABLE IX.—*Additional Loading of Feed-heater Engine No.* 711.

Engine No.	Class of Train. Tons.	Average lb. of coal per mile.	Actual load. Tons.	Additional load taken by Engine No. 711. Tons.	Per cent.
711	250 300	30·2	268·3	61·5	29·7
695	under 250	31·3	206·8	61·5	29·7
711	350 400	38·2	362·4	94·8	35·4
695	250–300	38·2	267·6	94·8	35·4

when the heaters were out of use, and also trains heavier than sister non-heater engines. Other engines showed similar results.

The engines fitted with the Type B arrangement are regularly employed for the heavier trains. Engines of one class in Upper Egypt were specially converted to meet the demand of the traffic department for more power, when it was not expedient either to purchase new stock or to strengthen the road sufficiently for engines of much greater weight. They have averaged loads about 20 tons greater, at a smaller consumption, than the ordinary sister engines, and are capable of dealing economically with still heavier loads. Engines Nos. 706, 714, &c., work in a link with large De Glehn compounds and heavy 4—6—0 type passenger engines, and handle, well to time, trains of 405 tons tare behind the tender; this is an increase of about 50 per cent. above the loads for which they were originally intended. They average regularly 350 tons compared with the 270 for which this class of engine is scheduled.

The limiting load of Engine No. 712 (Type C installation) has not been determined by steam production. This engine runs in the link of heavy trains, and, as far as ability to keep time is concerned, is thoroughly efficient. Its capacity is limited by the risk of running hot with the additional loads, at high speed. The bearing surfaces are not now up to the standard suitable for loading the engine to its maximum capacity. These points could be met in the case of new engines, while if, for these reasons, the fullest advantage cannot be taken of increased power after conversion, the engine will always give some increase in hauling capacity with very considerable economy in coal consumption. The additional load taken, at equal consumption, by the Egyptian State Railways heater engines, is greater than the estimates based on the diagrams given in the paper. Fig. 12 shows this to be correct, the consumption lines for heater and non-heater engines having different slopes. This must be attributed partly to the smokebox heater and its moderating effect on an increase of vacuum.

Practical Features.—Certain matters bearing on the value of the systems dealt with in this paper have been reserved for Appendix II, since they are largely affected by local conditions. Practical features of general interest will now be taken. As the Type A smokebox heater has been discarded, its features will not be discussed. The smokebox heater in the Type B installation, employed on engines like No. 706, is its superior in every way. The ½in. tubes used give no trouble. All the attention these heaters receive is to have the front tube-plate swept down with a wire brush when the smokebox is being cleaned. The tubes keep clean along the bore, and are self clearing with proper arrangements at the chimney end of the heater.

A flue door was introduced into the uptake in the case of the installation Type B and C (Appendix I), in order to pass the gases of combustion direct to the chimney, while raising steam, thus enabling lighting up to be carried out in the ordinary way. Without this means of temporarily cutting out the heaters the engines would take longer to get ready. In the last type (D) a flue door has not been necessary, for, owing to the more direct flow and to the use of tubes of rather larger bore (¾in.), the resistance to the gases is less, and lighting up takes its normal course.

The systems described require no special skill in operation, such as is needed, for instance, with compounds with independent cut off. The installation Type C requires the small amount of additional attention involved in the working of high degree superheater engines. With Engine No. 712 this is eliminated, so far as operation on the road is concerned, because the superheater elements are never raised to the limiting temperature, owing to the greatly reduced draught. It appears probable that, with so light a draught, the superheater element loops might be lengthened somewhat without harm, provided that the dampers were properly maintained.

In the Type B arrangement there are no adjustments to be made nor dampers to be considered, in connection with the smokebox heater, which needs no attention. No change is involved with this type in lubrication practice, the tempera-

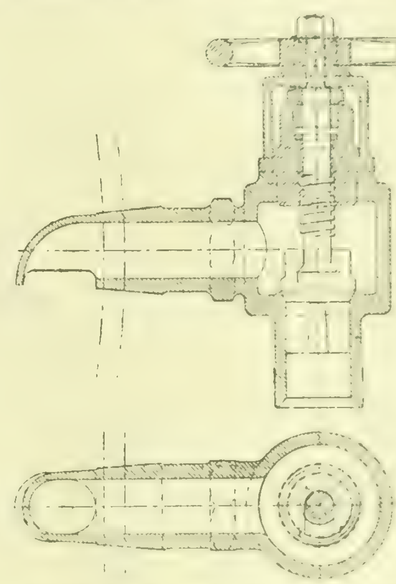


FIG. 16.—COMBINED BOILER CLACK AND BLOWING-THROUGH VALVE.

tures attainable with the waste-gas heater not being high enough to give trouble. Slide valves with sight-feed lubrication may, therefore, be retained. Mechanical lubricators are, however, gradually replacing the sight-feed type on the Egyptian State Railways, but quite apart from any connection with the heater systems.

The waste-gas smokebox heater is exposed to temperatures having a maximum in the neighbourhood of 750° Fah. At these temperatures there is no risk of damage, if the heater be empty of steam, when it is used for superheating. During any stop a certain amount of hot gas continues to pass from the firebox to the chimney by way of the heater, which is thus kept up reasonably near to its working temperature. The use of the blower, or the act of blowing off the brakes, increases this flow, and superheat results from the start. The smoke-tube superheater, on the other hand, takes several minutes to reach its working temperature, unless special arrangements are provided. These points have an effect on the economy shown in stopping service.

If the smokebox heater be used for feed-heating, it becomes effective as a thermal storage system during stops and periods of light work, such as drifting. The temperature in this heater may rise to 360° Fah. (with 180 lbs. pressure) during a stop, although the exhaust heaters are not then in operation, and there is thus a supply of hot water ready for transfer to the boiler at the first demand. The same applies in drifting. This form of thermal storage, taking advantage

of otherwise waste products, is a gain in every sense. Both in feed heating and in superheating the harder the engine works the higher the temperatures attained. On rising grades, therefore, when all the steam is needed, the feed temperature and superheat are both rather above the average. In normal working, with about 30 per cent. or so cut-off, the steam pressure in the exhaust-steam feed heaters amounts to about 3lbs. per square inch. The delivery from these heaters then has a temperature about 210° Fah. When working hard with later cut-off, the pressure may rise to 4·5lbs. per square inch, equivalent to a steam temperature of about 226° Fah., and slightly higher feed temperatures are obtained. In the case of the smokebox heater, the greater draught with the increased cut-off involves an increase in the smokebox temperature, favourable to an increase in feed temperature or superheat.

When smokebox feed-heating is installed, care must be taken when the regulator is closed, in order to avoid waste and the nuisance caused by blowing off. The use of the injector is then recommended instead of the pump, in order to reduce the risk both of blowing off, and of trouble from leaky heater tubes.

It is found advisable to blow the feed-heating system through at regular intervals. On the Egyptian State Railways this is done after about 300 miles, when over a pit or drain. A tumbler cock, fitted on the pump side of the main exhaust heaters, with a drain pipe set in towards the pit, is opened, and the special clack, Fig. 16, is then raised off its seat, by turning the screwed spindle, which engages loosely with jaws on the clack valve head. The heaters are thereupon blown thrown in series, including the smokebox heater, if used for feed-heating. The process is simple and quickly accomplished, so that it is readily adopted as one of the regular routine duties. A large part of the deposit is thrown down in the exhaust heaters, and this operation removes a considerable amount of scale-forming matter.

All heater systems dealt with are handled equally well by Egyptian as by European drivers. The fastest and heaviest trains on the system are regularly entrusted to both classes of men, indifferently. In order to get the best results, some little co-operation is necessary on the part of the men, but experience has shown that after a few days they become fully alive to the benefit of the systems, on the heavier trains especially.

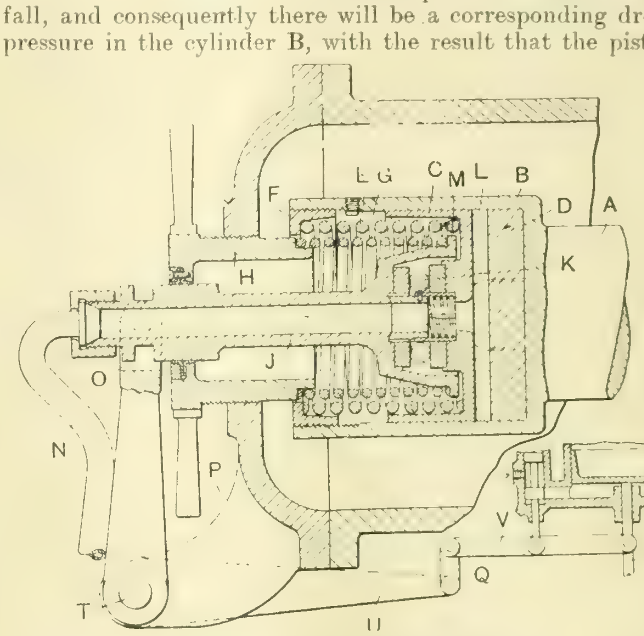
It is desired, in conclusion, to place on record an appreciation of the persevering efforts of those members of the Egyptian State Railways locomotive staff who, during the past 12 years, have been closely connected with the development of the various systems dealt with in this paper.

(To be continued.)

FRASER & CHALMERS' SPEED GOVERNOR.

THE accompanying illustration shows a design of speed governor of the type in which variable pressures are set up in a liquid by the action of centrifugal force, the pressures being utilised to effect the governing, the invention of Messrs. Fraser and Chalmers, Ltd., 3, London Wall Buildings, London, E.C., and Mr. B. F. Pochobradsky. A represents the end of the main shaft of a turbo or other machine, and is formed with a cylinder B. Within this cylinder is a sliding piston C, having on its inner face a number of radial vanes L, which are adapted to engage corresponding recesses in a block D, disposed at the bottom or closed end of the cylinder, so that the piston and cylinder rotate together. A spring E, disposed between the piston and a nut F which screws into the end of the cylinder, tends to force the piston to the right. Another spring G, arranged between a ring nut H that screws into an axial hole in the frame of the turbo, and a flange M of a sliding tubular member J, also tends to force the piston to the right. Between the tubular member J and the piston is a ball bearing K. The piston is centrally bored to establish communication between the tubular member J and the cylinder, and a liquid-tight joint is provided betwen the piston and the tubular member. The tubular member J is slidingly supported by the nut H, and terminates in a union to which is connected a flexible pipe N that communicates with a liquid reservoir. A recess in the tubular member J is engaged by two inwardly projecting pins carried by the forked end O of one arm of a bell-crank lever. This bell-crank lever is pivoted at T to a bracket P extending from the turbo frame, and its other arm U is connected to a link Q, which in turn is connected to one end of an arm V, the other arm of which is pivoted to the governor valve rod R, the latter being connected to the power piston of an oil relay S, which is adapted to operate the governor valve. The arm V is also pivoted to the rod of a piston valve controlling the oil relay S.

The operation is as follows: The space between the piston C and the closed end of the cylinder B is filled with oil from the reservoir. As the cylinder B and the piston C rotate with the shaft A, the oil is caused to rotate with them by means of the vanes L, so that the oil is forced radially by centrifugal action thus setting up pressure in the cylinder, which pressure varies with the speed of the shaft A. This pressure forces the piston C and tubular member J outwardly against the action of the springs E G, so that under normal running conditions these springs are under compression. If the load on the turbo machine is increased the speed of the shaft A will fall, and consequently there will be a corresponding drop in pressure in the cylinder B, with the result that the piston C



FRASER & CHALMERS' SPEED GOVERNOR.

and tubular member J will be moved to the right by the springs E G. This movement of the tubular member J causes the bell-crank lever to turn about its pivot T, and the arm U, link Q, and arm V to move downwardly, the latter arm turning about its pivot on the rod R. The result of this is that the piston valve of the oil relay S is opened, so that oil under pressure flows to the under side of the power piston of the relay which opens the governor valve wider. On the speed of the shaft A increasing beyond the predetermined limit the reverse action takes place. In order to regulate the governor, that is to say, to determine the speed at which the governor will operate, the tension of the spring G may be varied by means of the hand wheel on the nut H.

Automatic Voltage Regulation.—At a recent meeting of the West of Scotland branch of the Association of Mining Electrical Engineers, held at Glasgow, a paper on this subject was read by Mr. W. J. Belsey. At the outset he remarked that in the past sufficient attention had not been given to the subject of voltage regulation in industrial installations. To the central station engineer dealing largely with a lighting load, voltage regulation was one of the most important subjects with which he had to deal, because defects of such regulation were at once visible to the eye. Voltage regulation was, however, of just as much importance to the colliery engineer, and it was with the purpose of pointing out the desirability of a steady voltage that he had prepared his paper. Mr. Belsey thereafter dealt in detail with various types of regulators, losses in the generator fields and transmission lines, the operation of motors, together with the effect of voltage variation on lamps.

NOTES ON A BITUMINOUS-PRODUCER GAS ENGINE PLANT.*

BY J. R. COWELL.

It is my intention to give some particulars of gas engines using gas produced from ordinary South African bituminous coals. The notorious fiasco with the gas engines installed by the Johannesburg Municipality is not yet forgotten, nor has the influence of such failure ceased to be felt in South Africa. When last I had the honour of reading a paper on internal-combustion engines before this Institution, that scheme was only being discussed. Even at that time I gave some particulars of successful gas engine plants which were running in Great Britain using gas produced from bituminous fuel by the Mond process.

Had similar plant been installed in Johannesburg there is every reason to believe that the Johannesburg Municipality would still be using gas engines. An idea existed, and still seems to be held by many people, that ordinary South African coal is not suitable for use in gas producers, and also that the altitude caused difficulties. I would point out, however, that the altitude only affects the dimensions of the engines or producer plant, and that gas-engine plants are running successfully at altitudes of 12,000ft., or more than double the altitude of Johannesburg. And that with respect to South African coals, I know of no coal produced in South Africa which cannot be successfully used. It is true that some coals are more difficult to work with than others, and that the form of producer plant has to be modified to suit different fuels. The greatest difficulty presents itself with coals that run or fuse together very much, or that produce bad clinker, as in such cases extra labour is required. But when one considers that such fuels as green wood, sawdust, slack coal, and wet peat, containing as much as 60 per cent. of water, are today being used in gas-producer plants and running gas engines for power purposes in many parts of the world, it would be absurd to think for one moment that South African coals present any special difficulties.

All of you will be aware that the ordinary suction-gas plant burning charcoal or anthracite can be, and is, a most economical and successful power producer, and I am very pleased to be able to give you some particulars of a plant which has been working most successfully on ordinary Transvaal bituminous coal. This plant has now been at work for some 18 months, so that it is in no way in the experimental stage, and is the first really successful attempt to use such coal. It is situated at the Groenfontein Tin Mines in the Waterberg district of the Northern Transvaal. It was erected chiefly for the purpose of supplying power for treating large quantities of alluvial ground by hydraulic sluicing. The general arrangement of the plant is shown in Fig. 1, which gives plan and elevation: A being the gas producers, B gas coolers, C rotary tar extractors and pressure fans, D filters, E gas engine, F 3-phase alternator.

The gas-producer plant is of the suction-pressure type, and was constructed by the Power Gas Corporation Company, of Stockton-on-Tees, owners of the "Mond" and other patents. The plant was designed with special reference to the conditions under which it was to work, viz., continuous running, in a semi-tropical climate, at a high altitude, and with Transvaal coal, and has undoubtedly fulfilled the requirements. Samples of the coal which was proposed to be used were sent to the makers for trial and examination so as to obtain as far as possible the best results.

* Paper read before the South African Institution of Engineers, February 8th, 1913.

The producers are three in number, the capacity of each being half the rated full load of engine, so that one is always available as a stand by. During the first year's working only two of these were erected, so that there was not a spare one. The producer is very similar to the ordinary suction gas producer for anthracite, &c. It consists of a cylindrical steel shell with firebrick lining, the top being covered by a steel plate carrying the charging hopper, and provided with a number of poke holes to enable the fuel to be broken up, and any clinker to be loosened from the sides. There is also an annular steel boiler or vaporiser on the upper part of the firebrick lining, fed with water from a visible sight feed which provides the necessary steam for the gas producer. Round the main steel shell of the generator there is an outside casing provided with small circular doors opening to the air, and provided with a screw for adjusting the amount of opening. The lower part of the casing opens into the lower part of the gas-producer furnace below the firebars.

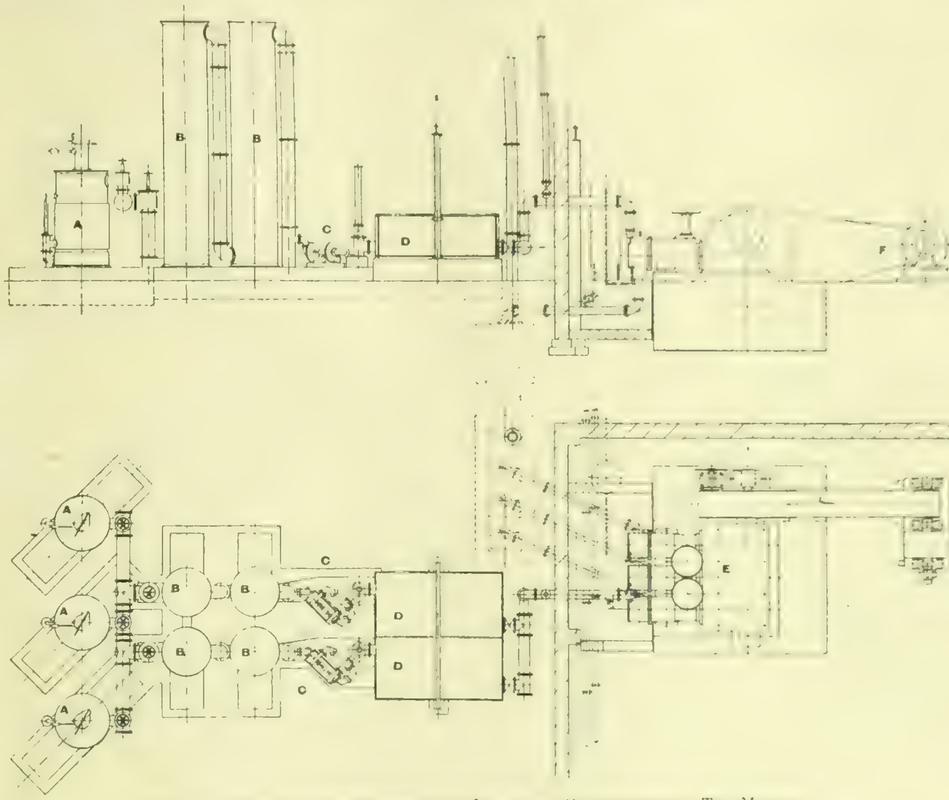


Fig. 1.—General Arrangement of Plant at Groenfontein Tin Mines.

The vaporiser outlet is also led into the top of this casing. By regulating the screws on the circular doors any required amount of air can pass into the furnace, and with this air is mixed the steam from the vaporiser, and thus the air is saturated with moisture, and being taken round the steel shell of the producer almost all radiation losses are taken up by the air and steam, the mixture thus going hot to the fuel. At the lower part of the producer are small doors for examining the fire and for cleaning the firebars. The firegrate is of conical shape, having horizontal openings which enable a straight bar to be thrust into the fire. The lower part of the firegrate is open, and a circular pipe is carried down from this some 2ft., ending in a water lute. This pipe is filled with ashes, &c., at starting, and forms a bed for the incandescent fuel. As any ashes or clinkers are formed, they (even of large size) can be readily removed from the bottom of the pipe without interfering in any way with the action of the producer, and without opening any doors. The side doors are, however, provided with a small water jet, which is turned on if it is desired to open the doors, and provides sufficient steam to prevent the gas falling off in quality whilst the doors are open.

The gas is taken out from the top of the producer, and is led up into the coolers B. These are divided into compartments, and are provided with a water-spray on the top of each for the purpose of thoroughly cooling the gas. The bottoms are open but sealed with a water lute, so that the tar and cooling water can run away freely. From the coolers

the gas is taken to the rotary exhausters and fans C C. These are in duplicate, each set of extractors, with its coolers and filter, being large enough for the full capacity of the plant. The rotary extractors throw off all tar and also draw the gas through the producers and force it under a slight pressure through the filters to the engine. The gas passes from the extractors to the top of the filter, whilst the tar flows downward to a water-sealed sump. Thus at all points of the plant no undue or dangerous pressures can occur, as the pressure is limited to a few inches of water. The filter D consists of a steel box containing wooden grids packed with shavings and sawdust. The gas filters from the top downward, so that if necessary to change the filtering medium it can be seen at once by taking off the cover. However, this filter is only put on as a safeguard, as rarely does the material have to be changed. I saw the side of the filter opened up a year after it was filled, and the material was hardly soiled.

The gas engine E was built by the Premier Gas Engine Company, of Sandiacre, and is of their well-known scavenger type. It is a 3-cylinder 3-crank engine, having cylinders 20in. diam. by 26in. stroke, and rated to develop 450 b.h.p. at sea level when running at 170 revs. per minute, and is the largest gas engine at present working in South Africa. It is fitted with heavy flywheel crowned for belt drive. The scavenger type engine is so named because the products of combustion are swept out after each explosion by a charge of air. With the exception of the use of a scavenger charge, the cycle of operations is the well-known 4-stroke one, and the action will be readily understood on referring to the section of this engine shown on Fig. 2, in conjunction with the following description:—

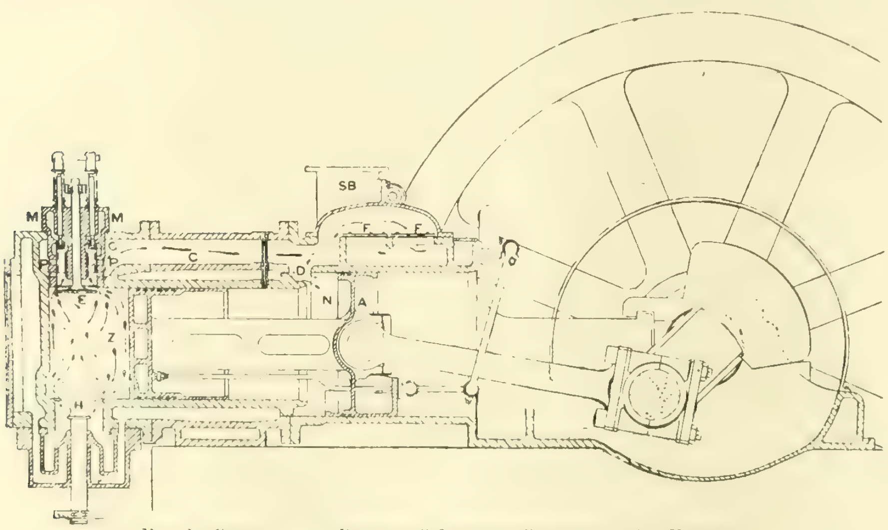


FIG. 2. SECTION OF "PREMIER" POSITIVE SCAVENGER GAS ENGINE.

Assuming that the engine is commencing its first or suction stroke, the admission valve E will be open, exhaust valve H nearly shut, and the gas valve G shut, but opening when the piston has moved a small distance on the suction stroke. The air supply is admitted through a pipe S B and thence through light lift valves F. It will be seen that the piston is of the differential type, and therefore that, when it moves forward, the air entering through the valves F will divide up, a portion entering, by way of the port D, the enlarged cylinder N, and another portion going through the passage C, ports P P and valve E to the motor cylinder Z. The gas is fed through a pipe and gas cock to the space marked M, whence it passes through the annular gas valve G, past the ports P P, where it meets and thoroughly mixes with air entering through them. Towards the end of the stroke the gas valve is closed, and shortly thereafter the admission valve I also, and at this stage the cylinder is filled with a mixture consisting of air and gas.

Second Stroke.—This mixture is compressed into the clearance space Z, while the air which entered the cylinder N is also compressed, but owing to the comparatively large volume of the clearance spaces in connection with it, the pressure behind the piston A rises to only about 5lbs. above the atmospheric pressure, whereas the pressure in the space Z rises to between 100lbs. and 180lbs., depending on the volume of this space, which is made suitable for the kind of gas used.

Third Stroke.—When the compression stroke is nearly completed, the compressed mixture is ignited by means of an electric spark, and the piston is propelled forward, the air which had been compressed by the piston A expanding and falling again to atmospheric pressure. Towards the end of this stroke the exhaust valve H is opened, and the pressure in the motor cylinder falls nearly to that of the atmosphere.

Fourth Stroke.—The piston moves backwards, expelling the products of combustion from the motor cylinder and re-compressing the air behind the large end A of the piston till the crank reaches the point shown on the diagram. At this point the admission valve E is opened, and the air compressed by the piston A flows through the ports P P and the valve E, spreading out and displacing the products of combustion in the upper part of the space Z, as indicated by the arrows. The continued backward movement of the piston keeps up the supply of air, which flows at an increasing rate through the diminishing space Z, and eventually clears out all the products of combustion from that space and fills it with pure and comparatively cool air.

A considerable excess of air is supplied by the piston A to ensure the complete clearing out of the space Z, and this excess passes through the exhaust valve. The latter remains open till after the crank has passed the dead centre in order to allow the pressure in the cylinder to fall to that of the atmosphere. Therefore, not only is the space Z filled with pure and cool air instead of hot products of combustion, but also the passage of a large excess of cool air over the valves and internal surfaces which come in direct contact with the flame helps to cool these surfaces, and thus in two ways tends to prevent that overheating which is the greatest difficulty met with in large engines. As the charge is cool before compression, it is possible to work with a higher compression than can be used in other engines without premature ignitions. The loss of heat to the cylinder walls is also less in proportion to the power developed, owing to the greater density and lower initial temperature of the charge, and for these reasons, a similar engine installed at the Birmingham University holds the record for thermal efficiency among gas motors. It will be seen that, although the system of scavenging is very complete, the engine is little more complicated than a non-scavenger engine, and possesses many mechanical advantages which are not found in other engines.

The governing of the engine is controlled by varying the quality of the charge. A typical indicator diagram is shown in Fig. 3. These were taken with gas of a value of 135-140 B.T.U. per cubic foot, and show the effect of governing by throttling down to quarter load and also the overload the engine is capable of carrying. Another special feature of the engine is the sparking plug. This is of the self-cleaning type, and I have here one for your inspection. The contacts are arranged so that the moving part has a slight end play, but is kept in position by a spring. At every compression and explosion the pressure in the cylinder drives out the movable striker, the spring forcing it back after the explosion, so that any dirt that might collect is being constantly rubbed off.

The dynamo F was made by the A.E.G. of their standard type, of a rated capacity of 300 K.V.A., 550 volts, 50 cycles, 3-phase.

Having thus briefly described the plant, I propose to give you some of the results obtained. The coals that have been used in the plant on regular work are round and nut coal from the Douglas Colliery and nut coal from the Premier Colliery and the Oogies Colliery. Douglas and Premier coals are chiefly used because they are the nearest collieries to Groenfontein and therefore the cheapest. I have, however,

tested on a smaller plant nearly all the available Transvaal coals, including Witbank, Tweefontein, South Rand Colliery, Springs, and miscellaneous coals obtained from the coal agencies, and have not yet found any that gave any special trouble. As before mentioned, coals that fuse and clinker are the worst to deal with, as they mean more labour in stoking. When the plant was first started a trial run was made, the load being put on by an adjustable water resistance.

On a continuous run of 12¾ hours 3,100 b.h.p. hours were produced from 4,095lbs. coal = 1·32lbs. per brake horse-power hour. For a four-hours' run 1,250 b.h.p. hours from 1,045lbs. coal = ·833lbs. per brake horse-power hour. The power developed during part of this run was up to 400 b.h.p. This was Douglas round coal, having an average calorific value of 11,600 B.T.U. per pound. The thermal efficiency works out at about 26·34 per cent. Tests made under ordinary working conditions about two months after the first trial run were as follows:—

Test, 10½ hours; engine running about half-load.

B.H.P. developed 177 b.h.p. average, carrying from no load to 233 b.h.p.

Weight of fuel consumed, 4,020lbs.

Weight of fuel consumed per brake horse-power hour, 2·16.

Clinker and ash removed, 350lbs.

Fire cleaned once per hour.

Water consumed in producer per pound fuel, ·41lbs.

Analysis of gas.

	Per cent.
CO_2	4·4
O	·42
CO	16·37
H	20·6
CH_4	2·92
N	55·29

Total combustible, 39·89 per cent.

The calorific value of this gas is about 160 B.T.U. per cubic foot. In this particular case the gas is specially rich in hydrogen. The average composition of "Mond" gas would be from 145 B.T.U. to 160 B.T.U. per cubic foot at sea level, and the composition as follows:—

	Per cent.
CO	23
H	17
CH_4	3
CO_2	5
N and moisture	52

Average ordinary suction-producer gas.

	Per cent.
CO	22
H	9
CH_4	2
CO_2	5
N	62

and the heat value about 130 B.T.U. per cubic foot. The quantity of gas used per brake horse-power hour is about 65 cub. ft. This is equal to an engine efficiency of about 30 per cent. of heat in gas. The producer will give an efficiency of about 80 per cent. of the fuel value in the favour of gas, so that the combined efficiency gives a heat value in brake horse-power of plant of 24 per cent. A high-class steam plant will give at most, say, 13 per cent. of the heat value of the fuel in the form of power.

Mr. A. Stuart, the manager of the Groenfontein Mine, has kindly sent me the following particulars under date of February 3rd, 1913: "As you are probably aware, our plant has not yet been run to its full capacity, but I hope by the end of the week to give it another 80 h.p. I am driving the mill and pumps off the plant, and the load factor should come up to about ·75 to ·8. At present it is not more than ·5, and has been as low as ·3, so that any figures relating to past running cannot be taken as representing the true facts. I give below an average consumption for the last eight months, and also some figures which you can accept as fairly reliable, showing what the plant will do when running with a good load.

"Particulars of a 360 h.p. Premier gas engine running on bituminous coal.

"Data average over an eight months' run. Average running time per month, 530 hours (no running from Saturday to Sunday midnight). Average coal consumption, 2·5lbs. per brake horse-power. Oil consumption, 7½ tins gas engine oil, 10½ tins heavy bearing oil, &c. Coal cost, 29s. 6d. a ton (2,000lbs.) at mine. Labour, one white driver and four natives, each eight hours' shift. Cost per brake horse-power hour, based on a coal consumption of 1·5lbs. per horse-power hour, and a running time of 550 hours per month. Total, 115,512lbs. Coal cost, 29s. 6d. per 2,000lbs. Total cost of fuel, £158. Running costs, including white and native wages, oil and sundry stores, native food, and workshop charges, £175. (Workshop charges average £35 a month, and could be taken out of this account.) Making a total of £333, or a cost per brake horse-power hour of ·55d.

"The plant runs usually 144 hours per week, i.e., from Sunday midnight to the following Saturday midnight. It was intended to run 30 days per month, but I understand that

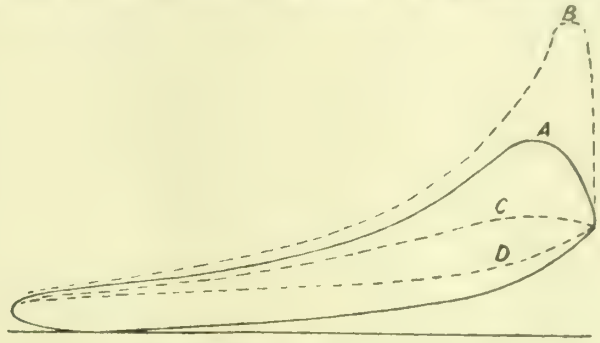


FIG. 3. TYPICAL INDICATOR DIAGRAMS.

A shows normal load card; B overload card (about 33 %); C approximately half-load card; D approximately quarter-load card.

the law does not permit the special work for which the plant is used to be carried on during Sundays. During January the plant was run 667 hours out of a possible 672 hours."

The efficiency of all producer gas-engine plants falls off very rapidly as the load decreases, so that the engines should be worked as near as possible to full load to get the best results. A considerable amount of tar is obtained from the tar extractors. This tar is different in composition from the ordinary gas tar, as the lighter oils are burnt from actual contact with the fire, and also the tar contains a considerable percentage of water, from 20 per cent. to 30 per cent. It is used in other countries for briquette making, road making, &c., and when freed from water makes a good preservative coating for ironwork, &c. No troubles, however, have been experienced from tar in the engine, as the gas is perfectly clean.

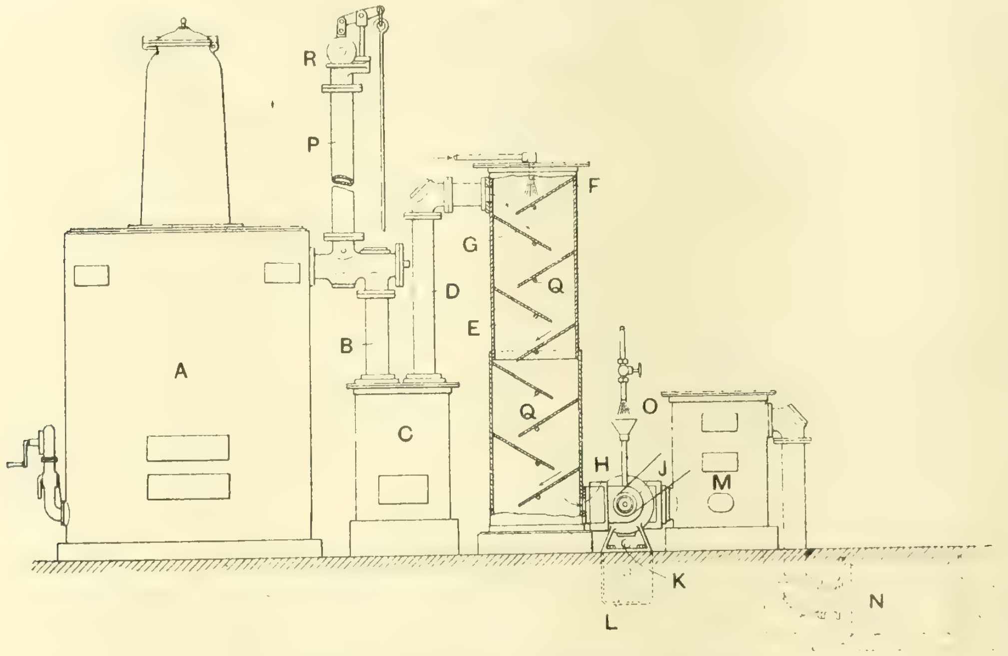
A Study of Blastfurnace Conditions.—The results of a series of blastfurnace tests are given in "Stahl und Eisen" by Dr Norbert Metz. The tests were carried out on a blastfurnace using minette ore and having six tuyeres. Its height from the base of the hearth to the throat is 55ft. 8¼in.; the hearth is 9ft. 2in. diam., and the cubical contents are 12,077 cub. ft. The average daily output is 120 to 130 metric tons of basic Bessemer iron, with a coke consumption of 2,645lbs. per metric ton. The average blast pressure is 4·82lbs. per square inch and the blast temperature varies from 800° to 870° C. The author's general conclusions from the tests are: (1) The decomposition of calcium carbonate is only brought about in a well-marked zone. (2) The separation of carbon is probably not the cause but the result of the furnace hanging. (3) Four distinct zones may be separated for the formation of hydrogen: (a) The highest part of the shaft, where the reduction of water by means of carbon-monoxide is the greatest. (b) The lowest part of the shaft, where a smaller amount of hydrogen is produced. (c) The bosh, where the last traces of water introduced with the charge are dissociated. (d) The tuyere zone, where water is introduced by the blast or by leaks in the water cooling arrangements. (4) The variations in blast temperature brought about by changing the stoves can be noticed until at least the upper part of the bosh is reached.

ARRANGEMENT FOR COOLING AND CLEANSING PRODUCER GAS.

In gas producers using bituminous fuel the cooler is used to reduce the temperature of the gases before they pass to the mechanically-driven tar-extracting fan, the gases hitherto having generally entered at the lower end of the cooler and passed upwards through material, such as coke, down which cold water flows so as to cool the gases on their way to the outlet at the top of the cooler, from which the gases pass by means of piping to the tar-extracting fan. Heretofore, it has also been proposed to purify coal gas by the action of water in divided streams, or sprays, impinging on the gas whilst being caused to pass downwards in a circuitous course between trays, or screens, in a closed chamber.

From bituminous fuel, such, for instance, as lignites, volatile matter deposits, particularly in the piping between the outlet from the top of the cooler and the inlet to the tar-extracting fan. In the case of some fuels, this deposit takes place so rapidly that this piping becomes choked even in a few hours, and causes stoppage of the working of the gas-producing plant. It has been found in practice that if water be caused to flow through this piping it will, in a great measure, keep it free from this deposit for a longer period, but an objection to this is that the volatile matter is washed to one end of the piping, and gradually accumulates there, and ultimately causes stoppage unless frequently cleaned out of the piping.

To overcome these objections, without using an additional quantity of water, the arrangement illustrated herewith has been designed and patented by Messrs. Tangyes, Ltd., Cornwall Works, Soho, Birmingham, in conjunction with Mr. James Robson. A is the generator in which the fuel is decomposed, and the gases produced before passing, by means of the piping B, to the dust-collecting chamber C. The gases pass from this chamber, by way of D to the top of the cooler E, where they meet a spray of cooling water admitted by the pipe F. The gases along with the cooling water then flow together downwards over, or through, a number of inclined baffle trays G to the bottom of the cooler E. The trays G are for bringing the gases and water into intimate contact with each other, so that the gases will be sufficiently reduced in temperature before leaving the cooler E. The trays G are loosely supported in the cooler E on pins Q, and these trays can be removed when desired, through the top of the cooler, for cleaning purposes. The cooled gases and the water then pass through the outlet H to the tar-extracting fan J, which is directly connected to the outlet H of the cooler E without the use of any intervening piping. In this way any accumulation of volatile matter that might tend to take place is immediately carried forward, by the flowing water, into and through the tar-extracting fan J. The water and volatile matter leave the tar-extracting fan J by the outlet pipe K, and run into a tar-collecting vessel L which is fitted with the usual overflow piping to allow of the water running away.



ARRANGEMENT FOR COOLING AND CLEANSING PRODUCER GAS.

The gases now having been freed (or practically so) from volatile matter, pass from the tar-extracting fan J to the dryer M, which contains a number of trays carrying wood, wool, or sawdust, for the purpose of removing any moisture before the gases pass through the expansion chamber N on their way to the engine. The tar-extracting fan J, which is mechanically driven, requires water to pass through it whilst it is in operation, but, as in the arrangement under notice, the water from the cooler E passes through the fan, a material reduction in the total quantity required is effected. The usual blow-off pipe P and valve R are shown fitted to the piping B for the purpose of carrying the waste gases to the atmosphere when blowing up the fire in the generator at starting.

CONDENSERS FOR TURBINES.

A MEETING of the Yorkshire branch of the Association of Mining Electrical Engineers was held at Leeds on Saturday last, when Mr. John A. McLay read a paper on "Condensing Plant for Steam Turbines," in which he expressed the opinion that the surface type of plant was the only one which should be used with a steam turbine. It was true that other types were cheaper in first cost, as, for instance, the ejector type and the low-level jet and barometric jet types, but the objections to their use with turbines overcame the advantage of their low first cost. A serious objection to any form of jet condenser at a colliery was the fact that usually the cooling water available was unsuitable for boiler-feeding purposes. The pure water from condensed steam was mixed with the injection or cooling water, and so was lost.

His reasons for advising the use of surface-condensing plants were that pure condensed steam water free from impurities was available for the boilers, the power consumption was low, the operation was easy and safe, and the maintenance was low. The surface plant was the most efficient in power consumption, but there were other points of greater importance whose value could scarcely be reckoned in figures, such as boiler-feed considerations, and boiler troubles due to bad feed water and air.

Dealing with the arrangement of a successful turbine installation with surface condenser, he suggested that the prevalent practice of placing the condenser in the basement should be done away with, and that the condenser should be put on the same floor as, and alongside, the turbine. He advocated bringing the exhaust branch out at the side of the turbine casing, and directing the steam into the bottom of the condenser, so that it travelled up through the condenser. This arrangement meant taking the circulating water in at the top of the condenser and out at the bottom, also taking the dry air pump suction from the top of the condenser and withdrawing the condensed-steam water from the bottom of the condenser. In addition, a connection should be placed in the exhaust branch of the turbine, and the feed make-up water sprayed into the exhaust pipe. A feed pump of the turbine type should be placed in series with the condensed-steam water extracting pumps, so that the water withdrawn from the condenser never came into contact with the air, but passed direct into the feed heater, economiser, and boilers. This arrangement, he considered, would be advantageous in various ways.

STANDARD COAL SPECIFICATION.

The following are the principal features of a model specification and conditions of contract for the purchase of coal by electricity works, which have been agreed upon by a committee representing the principal London firms of coal contractors on the one hand, and a committee representing the Associated Municipal Electrical Engineers of Greater London on the other. The former committee included Mr. G. C. Locket (chairman), of Messrs. Gardner, Locket, Hinton, and Co., Ltd., and chairman of the London Society of Coal Merchants; Mr. C. Fitzstephen Corr, of Messrs. Stephenson, Clarke, & Co., Ltd.; Mr. John Robertson, of Messrs. Hudson and Co., Ltd.; Mr. W. Valder, of Messrs. Wm. Cory & Son, Ltd.; and Mr. C. McRea, of Messrs. J. H. Beattie & Co., Ltd. The Municipal Engineers' Committee comprised the electrical engineers of Poplar, Stepney, Finchley, Shoreditch, and Hornsey, and was representative of Greater London generally.

Quantity.—(8) The quantity of coal to be delivered shall be ——— tons, but the purchasers shall have the option of purchasing 5 per cent. in excess of or 5 per cent. less than such quantity within the period of the contract, such option to be declared before the expiration of three-quarters of the period of the contract.

Rate of Delivery.—(9) The coal shall be delivered in regular weekly, monthly, or quarterly quantities as follows: ——————————, but the purchasers shall have the option of taking 10 per cent. in excess of or 10 per cent. less than such weekly, monthly, or quarterly quantity in any week, month, or quarter, provided that the total quantity so taken is within the limits described in Clause 8.

Weights.—(11) The purchasers shall pay for the "out turn" weight of coal delivered as measured on the Council's weighing apparatus excepting in so far as these weights may be affected by the conditions of the guarantee. In contracts where delivery is made in truck, and the purchasers cart the contents to works, the colliery weight to be accepted, unless the purchasers have the trucks re-weighed, full and empty, at receiving station.

Terms of Payment.—(12) The contractor shall render in duplicate upon his own and upon the purchaser's form a correct account of what is due to him by the 7th day of the month following the month in which delivery has been made, and the purchasers shall pay the contractor upon the certificate of the engineer within one month of the date upon which the correct account has been delivered to the purchasers.

Demurrage.—(16) In the case of coal sold in truck the purchasers shall be allowed three clear working days from the date of arrival of trucks at the railway station or sidings, such date to be determined by railway companies' arrival note, after which demurrage shall be paid to the contractors at the rate of 6d. per wagon per day. In the case of sea-borne coal four clear days at or off wharf shall be allowed, after which demurrage shall be paid by the purchasers to the contractors at the rate of 1d. per ton per day.

Engineer's Decision.—(20) All decisions of the engineer shall be subject to the provisions of Clause 23.

Strikes.—(22) In the event of a strike or lock-out of the workmen at the collieries or elsewhere, or if any circumstances whatsoever over which the contractor shall have no control, preventing delivery, the contractor shall not be required to deliver the description of coal herein contracted for during such strike, lock-out, or obstruction, and the quantity which would otherwise have been delivered shall be cancelled, but the contractor shall, if required by the purchasers, supply other coal approved by the engineer at a price to be agreed upon.

Arbitration.—(23) If at any time any question, dispute, or difference shall arise between the purchasers or their engineer and the contractor upon or in relation to, or in connection with the contract, either party may forthwith give the other notice in writing of the existence of such question, dispute, or difference, and such question, dispute, or difference shall be referred to arbitration of a person mutually agreed upon, or, failing agreement, to some person appointed by the President for the time being of the Institution of Electrical Engineers. The award of the arbitrator shall be final and binding on the parties. . . . This submission shall be deemed to be a submission to arbitration within the meaning of the Arbitration Act, 1899.

Specifications.—There are alternative specifications. A is for coal of a particular description, or "named" coal, while B is for coal guaranteed to have definite physical qualities as a fuel for steam raising purposes.

The principal features of this latter specification for "guaranteed coal" are as follows:—

The tenderer shall set out in his details the classes of coal for which he is tendering, corresponding with the classes referred to in the table of standards.

Testing.—(A) A representative sample shall be taken on delivery from each or any consignment, and shall be divided and sealed in three airtight vessels; the contractor shall be at liberty to be represented when the sample is taken, and shall be entitled to one portion thereof. The contractor shall have no opportunity at a later date of objecting to the manner in which the coal has been sampled.

(B) Samples taken in the manner herein defined shall be taken from each consignment and tested by the purchaser, or in the event of dispute by a competent expert who shall be aproved from time to time by the purchaser, and whose fees shall be paid by the contractor if the purchaser's test is confirmed. The tenderer is invited to set out in the tenderer's details the names of three experts, either of whom he is agreeable shall be employed.

Table of Standards to be Applied in Connection with Guaranteed Coals.

A.—Bituminous Durham and Yorkshire.

	Moisture.	Small Coal through	
1. Washed double nuts, 13,250 B.T.U.'s	8%	½" square mesh	15%
2. Washed single nuts, 13,000 B.T.U.'s	9%	⅜" ,, ,,	17½%
3. Washed peas, 12,750 B.T.U.'s	10%	¼" ,, ,,	20%

B.—Bituminous Scotch Washed Coals.

	Moisture.	Small Coal through	
1. Washed double nuts, 12,750 B.T.U.'s	10%	½" square mesh	15%
2. Washed single nuts, 12,500 B.T.U.'s..	11%	⅜" ,, ,,	20%
3. Washed peas, 12,000 B.T.U.'s	13%	3/16" ,, ,,	20%

C.—Semi-Bituminous and Pseudo Anthracite Welsh Washed Coals.

	Moisture.	Small Coal through	
1. Washed large nuts, 14,300 B.T.U.'s ..	5%	½" square mesh	15%
2. Washed small nuts, 13,900 B.T.U.'s ..	6%	⅜" ,, ,,	20%
3. Washed peas, 13,350 B.T.U.'s	6%	3/16" ,, ,,	20%

D.—Bituminous Durham and Yorkshire Dry Screened Coals.

	Moisture.	Small Coal through	
1. Double nuts, 12,750 B.T.U.'s	5%	½" square mesh	17½%
2. Single nuts, 12,500 B.T.U.'s	6%	⅜" ,, ,,	25%
3. Peas, 12,250 B.T.U.'s..............	6%	¼" ,, ,,	25%

E.—Bituminous Derbyshire and Nottinghamshire Dry Screened Coals.

	Moisture.	Small Coal through	
1. Double nuts, 12,250 B.T.U.'s	9%	½" square mesh	15%
2. Double screened small nuts, 12,000 B.T.U.'s	9%	⅜" ,, ,,	20%
3. Pea nuts, 11,500 B.T.U.'s..........	10%	3/16" ,, ,,	20%

F.—Bituminous Leicester-Warwick and South Staffordshire Dry Screened Coals.

	Moisture.	Small Coal through	
1. Double nuts, 12,000 B.T.U.'s	10%	½" square mesh	15%
2. D.S. small nuts, 11,750 B.T.U.'s	10%	⅜" ,, ,,	20%
3. Pea nuts, 11,250 B.T.U.'s..........	12%	3/16" ,, ,,	20%

Bonus and Penalty.—No variation of the contract price shall be made for any variation from the standard not exceeding one-twentieth, up or down, of the figures given in the table of standards.

(*a*) If the calorific value exceeds the standard value in British thermal units per pound, the price per ton shall be increased in the same percentage ratio as the increase in the calorific value.

(*b*) If the calorific value be less than the standard value in thermal units per pound, the price per ton shall be decreased in the same percentage ratio as the decrease in calorific value, provided always that the purchaser shall have the right to reject the whole consignment if the calorific value be more than 7½ per cent. below the standard.

(*c*) If the moisture be less than the standard percentage by weight, the weight of coal to be paid for shall be increased beyond the quantity actually weighed out by a percentage equal to the percentage decrease of moisture.

(*d*) If the moisture exceed the standard percentage by weight, the weight of coal to be paid for shall be decreased

below the quantity actually weighed out by a percentage equal to the percentage increase of moisture. Provided always that the purchasers shall have the right to reject the whole consignment if the total moisture exceed 1½ times the moisture given in the table of standards.

(*e*) If the percentage of small coal be less than the standard percentage by weight, the weight of coal to be paid for shall be increased beyond the quantity weighed out by a percentage equal to one-quarter of the percentage decrease of small coal, percentages to be taken on the bulk and not on the standard.

(*f*) If the proportion of small coal exceed the standard percentage by weight, the weight of coal to be paid for shall be decreased below the quantity actually weighed out by a percentage equal to one-quarter of the percentage increase of small coal, provided always that the purchasers shall have the right to reject the whole of the consignment if the proportion of small coal exceed 25 per cent. by weight, percentages to be taken on the bulk and not on the standard.

British thermal units shall be ascertained on coal dried at 220° Fah. for an hour by means of a Mahler bomb calorimeter.

Moisture shall be represented by the total loss in weight of the coal as delivered after air-drying and exposing to a temperature of 220° Fah. for one hour.

The percentage of sulphur shall be based on the analysis of the coal "as received," and must not exceed 2 per cent.

The sieves used for determining the percentages of "small" shall be of square mesh with openings in the clear to the sizes given.

The full form of tender may be obtained from Mr. Harold Wright, the hon. secretary of the Coal Contractors' Committee, c/o Messrs. Gardner, Locket, & Hinton, Ltd., 3, Fenchurch Avenue, London, E.C., price 10s. per copy.

NEW OPEN-HEARTH FURNACE DESIGNS.*

BY HERBERT F. MILLER, JUN.

For a long time I have believed that the gas and brick costs of open-hearth furnaces using producer gas could be greatly decreased by a change in the design of the port, which would materially reduce the first cost of the furnace, the rebuilding cost, and the repair cost. The defects of the present type of such furnaces, which has done duty for so many years, may be studied in Fig. 1, in which AA are the two air uptakes, B is the gas uptake, and C the end of the gas port.

In the present type of furnace, C is practically on the edge of the bath, and therefore combustion begins to take place at that point, but has no effect until the gas passes 5ft. to 10ft. into the hearth. As the furnace grows older, C moves back by reason of the burning or falling down of the arch. The furnace reaches its highest efficiency when C has moved a certain distance, but is still near enough to the bath for the overhead layer of air to hold the gas down on the bath, and far enough back to permit combustion to take place at some distance from the bath. This latter fact means that the temperature is sufficient to melt steel at the edge of the port. From this time on, the furnace decreases in efficiency. What is the reason?

As C moves further back, the gas is released from the gas port at a point where there is little or no overhead layer of air. The result is that the gas floats along the roof, with the air mostly underneath it. Why the air does not stay over the gas is readily seen in Fig. 1. The lines of draught naturally run parallel to the length furnace. The air uptakes being on the sides and the gas port in the middle, most of the air will naturally be drawn along the sides of the furnace, and the layer of air will be thinnest over the gas where it is most needed. Thus, as C moves back, the overhead layer of air becomes thinner until C has reached a point where it is in line with uptakes AA, and where there is no overhead layer of air. The gas then goes to the roof. The life of this type of furnace is 180 to 250 heats.

The foregoing history of the run of producer-gas furnaces, showing the causes of loss of control of the gas and its results in poor combustion, with consequent comparatively short run, suggests the question, Can a furnace be designed for producer gas which will have a good gas control and a good combustion to the end of a run of, say, from 400 to 700 heats?

This end can be attained by either of two designs, both of which involve the same principle of putting a single air uptake directly back of the gas uptake, as is shown in Figs. 2 and 3. In Fig. 2 the port has about one-third of the width of the hearth, whereas the present type has the full width. The roof of the port dips sharply, compressing the air down on the gas, and the roof of the hearth is gradually dropped to meet it. The gas-port arch is retained, although flattened to the width of the port. The end C is 6ft. to 10ft. from the edge of the bath. There is a small seal door on each side of the port at C to permit the repair of the port or the removal of the brick which might fall from the gas-port arch. The point C will move back slower than in the present type, because it will be less exposed to the flame, which will always be under the air.

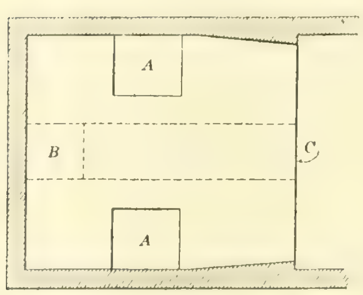


Fig. 1.

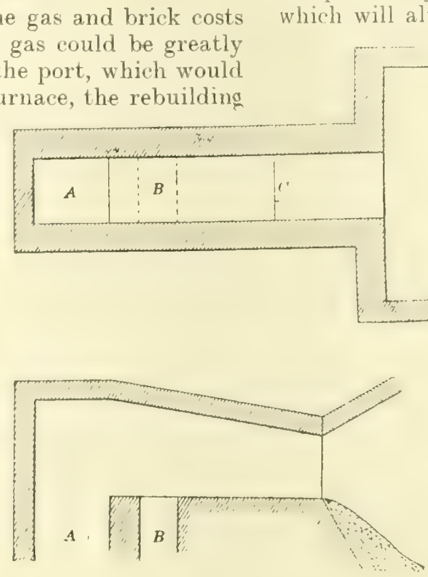


Fig. 2.

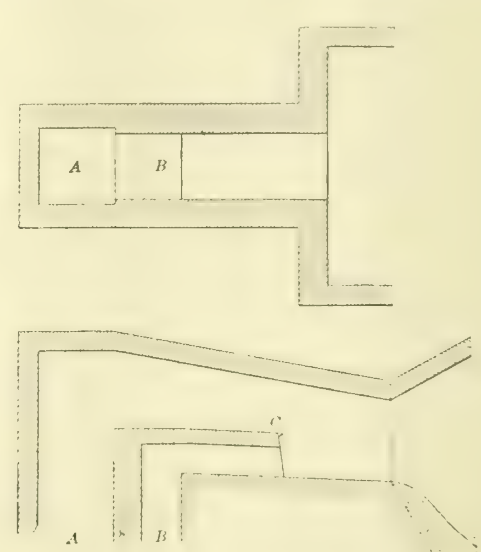


Fig. 3.

Arrangement of Ports for Open-hearth Furnaces using Producer Gas.

The possible defect of this design is that when the gas-port arch has become short, combustion will commence too far from the bath, and make a high gas cost. Another objection is that this design could not be applied to existing furnaces, because their ports would have to be lengthened considerably. If the flame in the above design can always be controlled, even when the gas-port arch has burned back to the gas uptake, why have a gas-port arch at all?

The design shown in Fig. 3 is the solution. Here it will be seen that the furnace is similar in outline to the present open-port type in use at Homestead. The air uptake A is back of the gas uptake, from which it is separated by a substantial wall. The gas uptake, which is as wide as the port, is 6ft. to 10ft. from the bath. The port is open and

* Abstract of paper read before the American Institute of Mining Engineers, February 19, 1913.

smooth, narrow and low. The small cross-section of this port assures a speedy union of the pre heated air and gas, resulting in a short flame of intense heat, which will be under control throughout the run.

Some may think that the gas rising at right angles to the air will make a high flame. If the port is low enough this will not occur. I have put a stream of air having a pressure of 70lbs. per square inch under a natural-gas flame, and found that there was very little deflection of the flame. This design could be applied to the present type of producer-gas furnaces. The only alteration of importance would be a reversal of the gas checkers from the outside to the inside position.

In building a new furnace a great saving in brick would be made in the ports, as can be readily seen. Repairs to the dividing wall can be made through small seals by the side of the gas port. The flame will always be under control, and the furnace should slow up only because of dirty checkers and insufficient draught. Natural gas could be used if desired by introducing it, as usual, at the sides and in front of the uptake G.

METHOD OF OVERCOMING LEAKAGE IN STEAM-METAL VALVE CASTINGS.

The greatest difficulty encountered in the manufacture of steam-metal valves is their leakage when tested. By this is not meant, of course, the leaks in the sense that the ordinary observer would imagine or around the joints or connections, but in the actual metal itself. In other words, when this kind of leakage occurs, the metal has the appearance of being porous. Valves are always tested before shipment and at varying pressures, depending upon the class of work for which they are to be used. Valves to be used for hydraulic work, or high-pressure steam lines, are always tested at a higher pressure than those to be employed for ordinary uses. Valves are generally tested after finishing, as it has been found easier to do so than in the rough casting, and the actual finished product is then tested, a matter that is now considered good practice. In case of leakage, the only loss is in the machine work done on the valve, and this is not considered of much importance, as the metal itself is not lost. The valves may be tested by water (hydraulic pressure), air, or steam, and it matters not what means are used, if the valve casting is porous, leakage will occur. The walls of the metal contain cavities through which water, air, or steam can pass.

The brasses and bronzes have the same properties as far as porosity is concerned, and it is a mistaken idea to believe that any one mixture will show less leakage than another. To be sure, there is a difference in the tensile strength, elastic limit, elongation, and reduction in area, but the factor of safety employed in constructing a valve is so great that it matters not what the physical properties are. Leakage is never caused by any lack of tensile strength in the metal itself, but invariably from the presence of dross blowholes, or other imperfections in the metal. To be sure, one mixture may cause more of these imperfections than another, but the proportions of copper, tin, lead, and zinc which may be present in a valve casting can vary within very wide limits without in any material way affecting the leakage, although it has been found that to obtain the necessary physical properties the mixture must remain nearly uniform. For this reason, it will be found that the steam-metal mixture used by each valve manufacturer does not vary to any great extent.

The cause of the leakage in valve castings is the presence of imperfections in the castings, and therefore it is a matter of foundry practice. Contrary to the belief of many persons, this is true, and there is nothing else, provided a suitable mixture is used, that will cause the difficulty. It is true, of course, that any metal with aluminium in it will give an abnormal number of leakages, but no one in the valve business would ever think of using such a mixture to put into valves. Given a suitable mixture, and the cause of leakages can be traced every time to foundry practice, either in the melting, moulding, pouring, or in the making of the pattern. The metal itself, however, is quite important, as there are some conditions which must be met, and the presence of aluminium in the metal, too much zinc, or other abnormal changes, will necessitate such radical variations in the foundry that it cannot be met, and the result will be an increased number of leaks. It is assumed, as almost invariably the case, that a mixture suitable for making valves is used.

The leakages in valve castings will run all the way from 3 to 25 per cent., depending upon the manner of melting and the foundry practice. A loss of 3 per cent. is excellent, and if it is possible to keep the leakage down to this amount, then the manufacturer should consider himself exceptionally fortunate and believe his foundry practice cannot be surpassed. In the best regulated establishment the leakage will ordinarily run about 5 per cent., when everything is going on normally and when the best methods for casting valves are used. As one maker says: "If the leakage of our valve castings remains at about 5 per cent. we are satisfied and are not disturbed, but if it begins to average greater than this amount, we immediately start and investigate in the foundry to ascertain the cause of the trouble." In many valve manufacturing establishments the percentages of leakages will run from 10 to 15 per cent., and it is considered regular practice. This, however, seems excessive, and would appear to indicate that there is some room for improvement.

On account of the leakages which occur, it is usually customary in many valve establishments to use new metals for the mixture to be used in the bodies and hubs or caps. The spindle, too, in large valves is usually made of new metal in order to obtain the necessary strength. The stuffing-boxes and other small parts are made of scrap. Exceptions to these rules are small valves or those which are to be used for low steam pressure or hot water. In such cases, all scrap is used. The use or avoidance of scrap does not determine, by any means, whether leakage will occur or not. In fact, it is a very common practice to lay leakages to the use of scrap, when, in reality, other things are the cause.

The following are the causes, as far as now known, of the leakages in steam-metal valve castings: (1) Pouring the metal too "cold"; (2) too short gate; (3) oxidation of the metal in melting; (4) walls of valve too thin; (5) aluminium in the metal; (6) sulphurising of the metal during melting; (7) core-box or pattern badly made, so that the casting is thick on one side and thin on other; (8) wrong metal mixture; (9) gated in wrong place; (10) use of large quantity of phosphorus as deoxidiser; (11) too little tin in the mixture; (12) sharp corners on the pattern.

The pouring of the metal too "cold" or at too low a temperature, as it is preferably called, is unquestionably the cause of more leakages than any one thing. It is the principal cause, in fact, and if valve-makers would look after this one feature they would find in it reason why their leakages have become excessive. Not only is it the principal cause of leakage, but it is a matter very easily brought about by regular methods of foundry practice. Valve-makers say: "We are making valves just the same to-day as we always did. Our patterns have not been changed in the least, we melt the same, use the same metal, and there has been no alteration in any way, shape, or manner, and yet we find our leakages running up to a high figure, sometimes reaching 25 per cent. It must be in the metal." When one comes to look carefully into this question, it will readily be seen that cold pouring is about all that is left for the reason of this abnormal number of leakages.

As there is a reason for all things, there must be an explanation for the leakage produced by cold pouring. To explain it without actually coming in contact with the pouring operation would be difficult, but as soon as one really sees the effect of cold pouring and that produced by hot metal, he will at once realise that there is much to the matter; and when he watches the streams of metal entering the mould, one "cold" and the other at the right pouring temperature, he will at once realise that the temperature is the most important feature of successful valve pouring.

When steam metal is poured, the stream of metal becomes covered or coated with a film of oxide, on account of its exposure to the air. This oxide rapidly breaks off, as the metal runs, and passes in with the metal. Watch a stream of steam-metal going into the mould at too low a temperature, and it will readily be seen. This oxide intermingles with the metal and acts like so much dirt. Frequently, if the temperature of the metal is too low, large pieces can be found

in the casting. This is dross (oxide) pure and simple, and is the cause of the leakage of the valve casting.

If the steam-metal is poured "hot" (by this is meant the temperature at which the best results are obtained), the stream of metal running into the mould will have a different appearance. It will run clear and clean and there will be no film of oxide on the surface, but instead there will be a blue flame caused by the burning zinc as it is exposed to the air. It is this burning zinc that really solves the problem, and the reason is as follows: Zinc acts as a strong reducing agent, but it does not burn in the air unless the right temperature has been reached; and this temperature seems to be that which will cause the zinc to burn. If the stream of molten metal is poured at too low a temperature, the zinc does not burn, but the tin, lead, and zinc in the metal oxidise and produce the oxide film as previously explained, and which enters the casting, causing leakage. When the temperature of the metal is right, the zinc burns on the stream of metal as it enters the mould and is exposed to the air, and actually prevents the formation of the oxides of copper, tin, and lead while it is itself being oxidised. The oxide of zinc, being so light, does not seem to cause the difficulty when it enters with the metal in the mould. It will be found, therefore, that when the steam-metal is poured at too low a temperature the castings will have a good appearance, but will leak. When the metal is poured at a higher temperature, so that the oxide film does not form on the stream of molten metal as it enters the mould, the appearance of the casting may not be quite as good, but a far less number of leakages will result. It may safely be said that the presence of dross (oxide) in the metal is the cause of nearly all leakages. Even in metal poured at the right temperature it will be found, and whether it is present in a greater or less quantity will determine whether the valve leaks or not. Pouring too cold is undoubtedly the real cause of valve leakages, and the effect is that small particles of oxide intermingle with the metal, enter the casting, and form channels through which water or air can pass.

The other causes are easily remedied. Too short a gate allows dross to enter the casting, and the result is the same as would be produced by dull pouring.

Metal overheated during the melting, or allowed to "soak" in the fire, after it has been melted, for some time is injured and oxidised. Such metal forms dross readily and does not run as clean. The result is the lodging of dross in the casting and leakage follows.

The fact that the pattern is "skinned down" to save weight is often the cause of leakage. There is a limit to the thinness of the walls, but the average valve-maker well knows that he cannot reduce the thickness too much. This cause of leakage is not a frequent one.

Aluminium in the metal is a frequent source of leakage when scrap is used. This metal is now so prevalent that it is not surprising that it enters scrap. Even a few hundredths of a per cent. will influence the leakage, although not in a marked degree. As the amount increases, then the leakages becomes greater. The reason is that aluminium oxidises very readily, and the oxide film on the stream of molten metal is not reduced by either hot or cold pouring or any other condition. The oxide enters the metal and forms channels through which water or air may pass.

Sulphurising the metal during melting, caused by the use of scrap high in sulphur or fuels which contain it, is the cause of a leakage "tendency." Metals containing sulphur are dirty and drossy, and this is instrumental in filling the casting with particles of dross.

The use of a poorly-made pattern can easily be remedied. Sawing a valve casting in half will readily determine whether the core fits the pattern so that the casting is even on both sides.

The use of a poor metal mixture is often instrumental in producing a greater percentage of leakages. Too much zinc, together with too little tin, will often cause it. Such metal must be poured at such a high heat, on account of its sluggish nature, that there is an abnormal amount of spelter smoke given off and this enters the casting, causing imperfections.

Gating in the wrong place may cause leakage, as it is well known that the portion of the casting near the gate, or at which the gate is joined, contains more dross than other parts.

Phosphorus, in the form of phosphor-tin or phosphor-copper, is often used for deoxidising purposes. If too much is used, it will cause pinholes in the casting, and these will form cavities through which air or water may pass.

Too little tin in the mixture will cause local shrinkage in valve castings. A certain amount is required to cause the valve to remain even all over and shrink normally. It will be found that steam-metal with too little tin will shrink in spots with a sort of depression. This may take place in the thick portions and usually does, but it results in the casting "drawing" and cracking. Cracks may cause leaks.

It often happens that in sharp corners shrinkage results with the formation of a slight crack. This often results in leakage at the crack. Corners should be rounded with suitable fillets.—"The Brass World."

TOOL STEELS.*

BY C. M. BIGGER.

WITH the high-grade tool steel manufacturer only three general classifications are usually recognised, under present conditions. These are what are known as the water-hardening carbon steels, alloy steels, and high-speed steels. The processes and methods of tool steel manufactures have wholly changed within the past 10 or 12 years. In addition to the usual grades and tempers of carbon steels, numerous alloy steels, such as nickel steel, nickel-chrome steel, nickel-vanadium steel, chrome steel, chrome-vanadium steel, vanadium steels, tungsten and tungsten-vanadium steels, are made to meet countless conditions and requirements.

Carbon Steels.—Let us first refer in our discussion to what are generally known as the water-hardening carbon steels. In 1908 a board on tool steel, appointed by the U.S. Navy Department to investigate the quality, shape, size, and brands of tool steels to be used in the Navy Department, reported these requirements:—

"That first in importance of the desirable qualities tool steel should have is that it shall be of uniform quality throughout for each and every grade.

"That it shall be of such chemical composition that it is not likely to fire-crack in hardening, under proper conditions.

"That this chemical composition should be such as to render it as little liable as possible to be ruined through carelessness in forging the tools or in subsequent grinding, and that the tools shall be as strong as practicable in the body.

"That the composition permit of forging through a comparatively wide range of temperatures; and, finally, the steel should be free from seams, cracks, and other surface imperfections."

When one reads these requirements he is impressed with the precautions that the manufacturer must take to make his steel "fool proof." Carbon steels generally group themselves into three classes. Each of these grades is made to meet a certain class of trade, and it will be found that all the manufactures are well equipped to yield a product of high standard in each class. Each of these grades are made in various tempers; that is, they contain varying percentages of carbon to suit the different conditions of service, and the heat of forging, annealing, or hardening, and the temperature to which the temper is drawn after hardening is regulated by the amount of carbon they contain. In general, steels containing a lower percentage of carbon require a higher heat in each operation than those containing higher percentages of this element.

Temper and Quality.—It may be well to state here that quality and temper of steels are two very different things. The temper of steel does not constitute its quality. The different grades and qualities of steel are made in the same temper, and the price is regulated by the quality. Quality in this sense is determined by the grades of material used in the manufacture of the steel, while temper means the carbon contained in the steel. I wish to call attention to the fact that the word temper in this sense must not be confused with the same word used in relation to drawing a hardened piece of steel. In drawing we say, draw to a light straw temper, a dark straw temper, a dark blue temper, a light blue temper, a black temper, as the case may be. In these connections

* Abstract of paper read before the Metal Trades Foremen's Club, Dayton, Ohio, February 27th, 1913.

the word temper has no relation whatever to the carbon contained in the steel. A great many times I have heard men say they wanted "a high-carbon steel," when in reality they wanted only a high grade of carbon steel. You can get the same amount of carbon in each of the grades mentioned.

In carbon steels the manufacturer usually runs his tempers in six classes: First, steels containing from 0·70 to 0·80 per cent. carbon; second, steels containing from 0·81 to 0·90 per cent. carbon; third, steels containing from 0·91 to 1·00 per cent. carbon; fourth, steels containing from 1·01 to 1·10 per cent. carbon; fifth, steels containing from 1·11 to 1·20 per cent. carbon; and sixth, steels containing from 1·21 to 1·30 per cent. carbon. These various tempers are used in the different grades for about the following purposes: In the 7 cent. grades, steels containing from 0·70 to 0·80 per cent. carbon are used for such work as anvil facings, pinch bars, blacksmith's tools, drift pins, &c.; steels containing from 0·81 to 0·90 per cent. carbon, for peen hammers, skate blades, cold chisels, &c.; those containing from 0·91 to 1·00 carbon, for chuck jaws, springs, hatchets, &c.; those containing from 1·01 to 1·10 per cent. carbon, for lathe centres, auger bits, axe bits, &c.; those containing from 1·11 to 1·20 per cent. carbon, for files, cold cutters, stone-cutting bits, and similar purposes; and those containing from 1·21 to 1·30 per cent. carbon, for dies for heading machines or similar purposes. The best grades in the different tempers are used for such purposes as button sets, bandsaws, drop forging dies, cutlery, large and small taps, threading dies, milling cutters, twist drills, chasers, gravers, and many other purposes.

Hardening and Tempering.—Considerable progress has been made in the hardening and tempering of carbon steels within the last few years; but a visit to the hardening rooms of many plants that are supposed to be up to date in all particulars reveals the fact that adequate equipment for hardening and a knowledge of the critical points of steel, with the changes that take place when it is heated, as well as others that occur in drawing the temper, are in many cases lacking. The results of not heating or drawing the temper accurately and the irregularities of antiquated methods of forging or treating have in a great many cases wrought disaster to a piece of good steel, and the entire blame has been placed on the manufacturer.

It is impossible in the scope of this paper to give accurate forging or hardening tempers for each grade or temper of steel, or even to state the exact degree to which they should be drawn. In general when forging, however, it is good policy to heat slowly and uniformly at first, before raising the temperature to the exact forging point, to ensure an even distribution of heat throughout the piece. When heating in a blacksmith's forge the fire should be kept clean and of ample volume to surround the piece completely. Always use extreme care so that the air blast does not strike the steel when heating; also see that there is a good bed of clean fire between the tuyere and the steel. Dirty fires are the cause of many failures, and in many cases of local overheating or burning.

When heating for hardening ample time should be taken to heat the steel slowly to the hardening point. Extreme care should be taken to protect it from the action of a direct furnace flame and also from any other causes that may interfere with successful hardening. The greater the care the better the results. Always be sure of a perfect distribution of heat. Avoid overheating thin parts or edges.

Hardening Expensive Tools.—A good suggestion to follow in hardening tools when the operator does not know the amount of carbon contained in the steel is to cut a small piece from the end of the original bar and harden it at different temperatures. A hardness test with a file and the appearance of a fracture will enable you to determine the least possible hardening heat that it will be necessary to give the steel to ensure the proper hardness. This plan should be followed especially when making up expensive tools, as the results obtained will more than compensate for the amount of labour expended.

Best results in hardening are obtained when the heating is done in a muffle furnace, either oil or gas fired, as in these furnaces the steel does not come in direct contact with the flame. The successful hardening of delicate tools depends largely on the condition of the atmosphere to which the steel is subject; whether it is oxidising, reducing, or neutral in character. Carbon steel, it is generally conceded, can be hardened most favourably in an atmosphere where the oxygen in the air is entirely consumed. In an atmosphere of this nature the scaling or oxidation is reduced to a minimum. It is because of these general conditions that the electrically heated furnace is now spoken of so highly for hardening purposes.

It is very evident that to get the best results from tool steels they must be hardened and tempered properly. To do this certain amounts of apparatus are necessary, such as proper heating furnaces, adequate cooling baths, the proper tools and tongs, and, last but by no means least, a good pyrometer. Whether the operation is forging, hardening, or tempering, there is for each grade and temper of steel, and the particular use thereof, a well-defined temperature point that alone gives the best results in work. A marked variation from this temperature may do irreparable damage. The use of a suitable pyrometer is recommended for all hardening purposes, and a pyrometer or thermometer for obtaining the temperatures of all drawing baths. When using a pyrometer reasonable care must be exercised to see that the readings are truthful and reliable. Pyrometers may frequently go wrong, and unless the operator is an experienced hardener the results may be disastrous.

Cooling Baths. In most cases water is used as a hardening medium for carbon steels. Where extreme hardness is desired, a solution of salt water or brine or ice water can be successfully used. In other cases articles to be hardened are quenched in a bath of water, and before they are cold or have ceased contracting they are removed from the water and placed in oil. This is true of such articles as milling cutters, some forms of punching dies, taps, reamers, &c. Some steels require to be quenched in oils only. Lard, fish or whale oil is preferable for this purpose, but any recognised light tempering oil will do. However, heavy fatty or mineral oils should be avoided. In all cases the cooling baths should be of ample size, and a temperature as nearly uniform as possible should be maintained. All tempering of carbon steel should be done in an oil heated bath or other medium by which the drawing temper can be kept uniform. For taps, dies, reamers, milling cutters, &c., relieving the strain is all that is required. In other tools where toughness is the predominating factor the temper may be drawn slightly more.

When we say a piece of steel is decarbonised, we mean that the surface, for a few thousandths of an inch deep, has lost some of its original carbon during the process of annealing. All annealed steel is more or less decarbonised, and when intended for tools of any description that are to be subsequently hardened, sizes large enough to permit the removal of at least $\frac{1}{32}$in. on a side should be ordered. Failure to remove the outer surface of annealed steel of all grades or tempers will consequently give trouble in hardening.

Alloy Steels.—The term alloy steel is used to distinguish steels containing nickel, chromium, vanadium, titanium, or other elements in varying percentages, from the carbon steel in which the characteristic properties are dependent upon the presence of carbon alone. Up to the last two or three years nickel steel was perhaps the most used of all the alloy steels. It is usually made in the open-hearth furnace and contains from 0·20 to 0·50 per cent. carbon and about 3·50 per cent. nickel. Lower carbons than these are sometimes used for case-hardening purposes. This steel has many excellent mechanical qualities, and is generally conceded to be a good free cutting steel.

Referring to chrome steel, I am personally familiar with a variety of this steel containing from 0·80 to 1·20 carbon and from 3 to 3·50 per cent. chromium. This steel is used specially for hot work with excellent results, as for gripper dies, bolt header dies, riveting dies, and what are known in fabricating or boiler shops as bull dies. It can be easily annealed under exactly the same conditions as carbon steel, excepting that the annealing temperature is slightly higher; in this state it is very free cutting. When properly hardened and used for the purposes stated above, the users expect to get from six to ten times as much work from this steel as from ordinary die steels. Actual records show where riveting dies have driven over a quarter million 1in. by 2in. rivets without redressing.

Chrome-vanadium steels of numerous types are now manufactured. The service and test records of this class of steel show remarkable results, and its use will be greatly increased in the near future. Vanadium in steel is supposed to impart anti-fatigue properties. Under proper heat treatment this steel has been made to assume higher physical properties (expressed by the elastic limit, tensile strength, torsional test, impact test, and bending test) than any other type of steel. It is largely used in automobile construction for driving axles, for gears, pinions, pins, pressed or stamped parts, valve and valve steam, &c.; in fact, it gives excellent service in any parts calling for strength or durability. It is especially recommended for all spring requirements, and it is guaranteed to have three times the life of carbon steel spring.

Tests were made recently to determine the relationship between carbon spring steel and chrome-vanadium steel for motor-cycle springs. The greatest durability was the prime requisite of these springs, and the test was of vital importance. A very ingenious device was constructed so that the end of each spring was made to oscillate under force from a shaper at the rate of 4,980 vibrations per hour. It was found under proper heat treatment that carbon steel stood this test for an average of 36 min. only, while chrome-vanadium steel averaged 5 hours and 40 min. The chrome-vanadium steels require a special heat treatment. The springs referred to were heated to 1,350° Fah. and quenched in oil; the temper was then drawn to 700° to 900° Fah.

Chrome-vanadium steel for gears is proving the superiority of this class of steels. For this purpose it is made in case-hardening and oil-hardening tempers. The oil-hardening type contains about 0·45 to 0·60 per cent. carbon, so that by merely heating to the proper temperature and quenching in oil the gears are made sufficiently surface-hard to withstand all ordinary wearing conditions, while the core is tough and strong.

High-speed Steel.—Since 1901 high-speed steel has had a rapid growth and extensive sales. Only those who have kept in close touch with its manufacture and uses can appreciate the tremendous amount of work in the way of efficiency tests that has been necessary to bring it to its present state of perfection. With the introduction of vanadium into this grade of steel about 1908 a very important step was taken. Now all good grades of high-speed steel contain more or less of this element. In regard to this, numerous tests have proven that a steel that will cut at 10 per cent. faster speed will last twice as long between grinding (if the speed is not changed), and a steel that will stand a 20 per cent. faster speed will run four times as long between grindings. A steel that will stand 30 per cent. faster speed before it reaches the breaking-down point will last eight times as long without sharpening, if the same speed is used.

Each addition of 0·3 per cent. of vanadium adds 10 per cent. to the possible cutting speed and doubles the life of a tool at the same speed and feed. It has been shown that 0·3 per cent. vanadium allows 10 per cent. increased speed or 10 per cent. more metal removed in the same time; that 0·6 per cent. vanadium allows 20 per cent. increased speed or 20 per cent. more metal removed in the same time; that 0·9 per cent. vanadium allows 30 per cent. increased speed or 30 per cent. more metal removed in the same time. Stating the effect in terms of increased times between grindings, it has been shown that 0·3 per cent. vanadium doubles the time between regrindings, that 0·6 per cent. vanadium quadruples the time between regrindings, and that 0·9 per cent. vanadium gives eight times as much metal cut between grinding at the same speed and feed.

I contend that high-speed steels containing vanadium will run much longer between sharpening, in proportion to the quantity of vanadium they contain, up to $1\frac{1}{4}$ per cent. High-speed steels are used for such purposes as lathe and planer tools; it is invaluable for swan-neck tools; special dies, which have heretofore required very great care in hardening; punches, boring tools, cutters, straight drills, twist drills, special taps, hard-wood knives, and all kinds of milling cutters, and it is especially valuable for involute or gear cutters in which accuracy of form and long life are necessary. These steels are usually furnished annealed by the manufacturer, and it is the best policy to permit the manufacturer to do all the annealing for the user. However, should it be found necessary to anneal a piece of this steel, the following is a good method of procedure:—

"For all annealing purposes use an iron box or pipe of sufficient size to allow at least $\frac{1}{2}$in. of packing between the steel to be annealed and the sides of the box or pipe. Pack carefully with powdered charcoal or lime. Cover with a cap which should be air-tight. Heat slowly to a full red heat, say, about 1,500° to 1,550° Fah., and hold at this heat from 2 to 8 hours, depending on the size of the piece being annealed. Cool as slowly as possible and do not expose the steel to the air until it is cold."

Electrically or gas-fired furnaces designed for high heats are now made to do very satisfactory work in hardening this class of steel. Tools to be hardened should be heated to a white heat just below the blistering point. The heat should be the highest possible in view of the importance of preserving the cutting edge. The higher the heat the better the results. Proper care should be taken to heat slowly and uniformly to the proper hardening temperature, also to avoid overheating thin parts or sharp edges. Tools of this class of steel can be either quenched in oil or other semi-active medium, or in some cases the whole tool can be cooled in the air blast. In all cases the temper should be drawn to relieve the strain, or to the proper degree to get the best results.

CUPOLA CONSTRUCTION.

Under the auspices of the British Foundrymen's Association, Mr. M. E. Gallon delivered a lecture at Newcastle on Saturday last on "Cupola Construction." He stated that the cupola was one of the most important items in the great iron-founding industry in the country. When cupolas, or iron furnaces, were first constructed he could not definitely tell them, but to come down to comparatively recent times, say, 150 years ago, cupolas were made square and in rectangular oblongs. They were built of red brick, and the inside was lined with any refractory material that the ironfounder could get. Their method of blowing was to place a blast main in the ground, and from this they led away two leather hose pipes, to the free end of which were two copper nozzles. These cupolas served their purpose fairly well at that time, but as the commerce of the world increased, the engineer demanded more castings, and it became necessary to improve upon the old condition of things. This incentive to inventive genius resulted in square cupolas giving place to the cylindrical or round cupolas, and the rectangular oblong cupolas to the eliptical cupolas, both of which they had with them to-day. Mr. Gallon afterwards commented on the cupola invented by Woodward, which was worked by a jet of steam placed in the chimney. Referring to the Steward rapid melting cupola, he said that the method of blowing was similar to the Grenier system. Various other cupolas, notably those in use at the lecturer's own foundry at Dunston-on-Tyne, were dealt with.

CORRESPONDENCE.

Burglar Alarms.

To the Editor of "The Mechanical Engineer."

Sir,—I should be glad if any of your readers would give their experiences of the various kinds of burglar alarms—not necessarily confined to the ultimate test—as suited to an occupied house, *i.e.*, where communication with a police station or boy messenger's office is not important. I am aware of the system of "treads" in the floor, working bells and lights by clock-work, which has been satisfactorily tried, but desire to know of any other efficient methods. Yours faithfully,

"B."

Air Pumps for Low Vacuum.

To the Editor of "The Mechanical Engineer."

Sir,—I should be obliged if any of your readers would kindly furnish me with the address of makers of small portable power-driven air pumps, capable of producing a vacuum down to about ·001 millimetres, such, for instance, as is produced in vacuum or Moore light tubes.—Yours, &c.,

"A Subscriber."

INDUSTRIAL AND TRADE NOTES.

Important Industrial Establishment for Canada.—According to the "Montreal Gazette," Sir William Arrol & Co., Ltd., are arranging to establish constructional steel works in Montreal for the production of all types of cranes, hydraulic machine tools, and other appliances, and otherwise to extend their operations in the Dominion.

Tinplate Trade Depression. Discussing the condition of the tinplate trade in his monthly report, Mr. Thomas Griffiths (South Wales organiser of the Steel Smelters' Union) says the trade is going through very trying times. "The 117 mills that were rushed up during the last two years," he says, "are contributing their quota towards an already glutted market. What the result will be no one can predict, for some employers are well placed for orders, while the majority of them are simply scraping what they can get. During the miners' strike the Americans captured several of our markets."

Petroleum Production in Roumania.—The total production of crude petroleum in Roumania in 1912 amounted to 1,807,000 metric tons, as compared with 1,545,000 metric tons in the previous year. The contract for the construction of the Baicoi-Constantza pipe line has been awarded to a Dutch firm, acting on behalf of a United States company; the contract price is £167,209. A commencement has been made with the work, which will, it is expected, be completed in from six to eight months. There is to be a 10in. pipe from Baicoi to Ploeshti and one 11in. and two 5in. pipes from Ploeshti to Constantza.

Electrically Propelled Sea-going Vessel. The launch of the "Tynemount" which took place from the yard of Smith's Dock Company, Ltd., at Middlesbrough, on the 26th ult., marks an interesting development in marine propulsion. The vessel is fitted with the Diesel engine in combination with electric transmission to promote efficiency and reliability. The vessel, which is for use on the Canadian canals, is the first sea-going ship to be electrically propelled. She measures 250ft. in length, 42ft. 6in. in breadth, 19ft. in depth, and will carry a total deadweight of 2,400 tons on a mean draught of 14ft. in fresh water. The oil engines are two in number, each of 300 brake horse-power, of the standard type, developed by Messrs. Mirrlees, Bickerton, & Day, Stockport, and the electric installation throughout is by Messrs. Mavor & Coulson, of Glasgow. The hull has been built by Smith's Dock Company as a sub-contract from Messrs. Swan, Hunter, and Wigham Richardson, Wallsend-on-Tyne, who obtained the order from the Montreal Transportation Company through Messrs. John Reid & Co.

Shipyard Wages.—The claim which has been made by the shipyard trades for an advance in wages was again considered on the 28th ult. at a conference held in Carlisle between the Executive of the Shipbuilding Employers' Federation and representatives of the trades unions. The employers first met the Standing Committee of the Shipyard Trades Unions. On behalf of the employers it was urged that trade conditions did not warrant an advance of wages. There were decided indications, they stated, that the "boom" in the industry had reached its zenith, and that already there was a decline in the demand for new tonnage. The men's representatives, on the other hand, argued that the great demand for labour implied a prosperity which justified an increase. No agreement could be reached with these conflicting views, and the employers proposed that time should be allowed to prove or disprove the theories which were advanced as to trade conditions and prospects. The men, however, did not agree to this, and after about two hours' sitting the conference adjourned. The employers afterwards met the Executive Council of the Boilermakers' Society, and the proceedings were practically the same. The boilermakers do not come under the shipyard agreement, which provided for calling a further conference, but it is expected that they will follow the same procedure in the matter as the other shipyard trades.

British Trade with Brazil.—A report by the Acting British Consul-General at Rio de Janeiro on the trade of that district in 1911 and 1912 states that it is almost impossible to attempt to enumerate in detail the directions in which British trade might be increased. The years 1911-12 have been marked by developments in nearly all branches of Brazilian commerce. Besides taking a large share in the supply of capital to Brazil, the United Kingdom is chiefly concerned with the import trade in manufactured articles, machinery, iron and steel goods, &c., being the items of chief interest. Although a considerable increase has taken place in the importation of industrial machinery, it is regrettable that practically no increase has to be recorded in the importation of agricultural machinery. It is gratifying to notice that during the years 1911 and 1912 there was a considerable increase in the number not merely of commercial travellers but also of heads of firms, engineers, and really representative men in various branches of industry in the United Kingdom who have visited Rio de Janeiro. There appears to be no reason to suppose that British manufacturers cannot keep, and even increase, that proportion of the Brazilian import trade which is now theirs. Too great emphasis cannot be laid on the value of the personal factor, not only in securing business, but also in obtaining impressions and ideas at first hand of the needs and possibilities of the Brazilian market.

Russia's Iron Industry. The British Vice-Consul at Berdiansk reports that the large South Russian ironworks were in a most prosperous condition in 1912, and paid large dividends. With one exception, however, ironworks have not attracted British capital, although an immense iron and coal industry has sprung up, in which Belgian and French capital has been invested. The main object the pioneer company (a British company) had in view was the production of rails for the Russian Government, and the plant was on a heavy scale, with just enough light rolls to produce the ordinary sections necessary for its own use. Following in its footsteps, all the succeeding ironworks, which later sprang up like mushrooms in the Donetz district, were fitted out on the same plan, with machinery capable of producing rails, girders, beams, heavy angles, boiler plates, sleepers, &c.; but the fact that the market required a large quantity of ordinary wrought iron squares, rounds, flats, &c., was entirely overlooked, and even at the present time the question of where to obtain their raw material is becoming a serious problem for hundreds of iron-working concerns. The machine works especially are feeling the want of raw material, and the Association of Russian Agricultural Machine Manufacturers propose to open new works specially for supplying their wants in iron and steel.

World's Record Output of Copper.—According to statistics compiled by Messrs. Henry R. Merton & Co., the production of copper last year was the largest on record. The total is given as 1,004,485 tons, an increase of 132,565 tons as compared with 1911, equal to about 15 per cent. This in turn was also the largest increase in any one year. The increase was largely due to higher prices and consequent activity in mining, particularly in the United States, where the output increased from 483,865 tons to 554,835 tons. The production in Japan increased by 10,500 tons to 65,500 tons; in Spain by 8,000 tons to 58,930 tons; in Australasia by 5,180 tons to 47,020 tons; in Canada by 9,780 tons to 34,710 tons; in Chili by 7,710 tons to 37,305 tons; in Mexico by 9,940 tons to 70,845 tons; and in Russia by 4,700 tons to 33,010 tons. Among the countries in which a smaller production is recorded are Peru, Argentina, and Africa. The figures show that the world's production of copper has steadily increased almost without interruption for the past twenty years. Prices, too, have risen, the average of standard copper on the first of each month in 1893 being £43. 6s. 9d., as compared with £73. 1s. 3d. in 1912. It is pointed out that, in spite of the large amount of copper produced last year, the visible supplies in Europe and America decreased by over 20,000 tons, giving a consumption of, approximately, 1,024,500 tons. In 1911, when the production amounted to 871,920 tons, the visible supplies were reduced by 19,457 tons, so that the consumption in 1912 increased by slightly over 11 per cent.

METAL QUOTATIONS.

TUESDAY, APRIL 1st.

Aluminium ingot		9[illegible] per cwt.
" wire, according to sizes, &c.	from	112/- "
" sheets " "	"	120/- "
Antimony	£31/-/- to	£33/-/- per ton.
Brass, rolled		8[illegible]d. per lb.
" tubes (brazed)		9[illegible]d. "
" " (solid drawn)		$8\frac{3}{4}$d. "
" " wire		8[illegible]d. "
Copper, Standard		£67[illegible] per ton.
Iron, Cleveland		$66/10\frac{1}{2}$ "
" Scotch		$72/10\frac{1}{2}$ "
Lead, English		£16/17/6 "
" Foreign (soft)		£16/8/9 "
Mica (in original cases), small		6d. to 3/- per lb.
" " " medium		3/6 to 6/- "
" " " large		7/6 to 11/- "
Quicksilver		£7/10/- per bottle.
Silver		$26\frac{1}{2}$d. per oz.
Spelter		£24/1[illegible] per ton.
Tin, block		£218/5/- "
Tin plates		14/- "
Zinc sheets (Silesian)		£28/-[illegible] "
" (Stettin; Vieille Montagne)		£28/2/6 "

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Detectors of combustible gases. Philip & Steele. 27281.
Ejector pumps, condensers, and compressors. Rees. 27471.
Rotary engines applicable for employment as a pump or compressor. Harper. 27493.
Rotary compressors for two-stroke cycle internal-combustion engines. Zoller. 27716.

1912.

V pulleys. Hutton. 591.
Valve controlling devices of plant using elastic working fluid from a plurality of sources. Parsons, Carnegie, & Parsons. 3116.
Means for transmitting power to Pelton wheels and turbines. Forman. 5512.
Ships. Knapp. 5807.
Control of the transmission of power between shafts with variable velocity ratios. Thomas. 5831.
Belt shifting mechanism. Cowley & Cowley. 5840.
Railway signalling apparatus. Mellor. 5850.
Internal-combustion engine. Harvey. 6029.
Rubber disc pump valves. Howland. 6089.
Internal combustion engines. Tuckfield & Garland. 6169.
Threading dies. Smith. 6211.
Recording apparatus for testing machines. Denison. 6229.
Machines for cutting and treating peat. Zelenay. 6256.
Boilers for heating systems. Gaillard. 6266.
Two stroke cycle internal combustion engines. Von Schmidt. 6274.
Carburetters for internal combustion engines. Morris. 6291.
Mode of and means for finishing sand moulds for casting purposes. William Mills, Ltd., & Mills. 6310.
Water tube boilers. Chantiers et Ateliers Augustin Normand. 6383.
Prevention of back lighting in combustible gaseous mixtures. Bone & McCourt. 6738.
Marine and other fluid pressure engines. Werry. 6786.
Aeroplanes. Westlake & King. 6810.
Carburetters for internal combustion engines. Hamilton. 7190.
Steam generators. Parkyn. 8047.
Apparatus for producing bars and tubes directly from molten metal. Pehrson. 8485.
Railway journal boxes. Smith. 8521.
Valve gear for internal combustion engines. Wolseley Tool and Motor Car Company, and Sweeney. 8928.
Manufacture of compressed fuel. Thomas & Hannay. 9065.
Superheaters for locomotive boilers. Spencer. 9097.
Multi cylinder suction and forcing pump. De Mirman. 9718.
Means for starting internal combustion engines. Brooks & Holt. 10996.
Priming devices for internal combustion engines. Annable. 11074.
Wire rope coupling clips. Weetman. 11096.
Construction of mandrel for use in the manufacture of tubes. Hayes. 11187.
Rotating mechanism for mechanically-driven hammer drills. Puschel. 11778.
Gear wheel grinding machines. Ward, and Gear Grinding Machine Company. 12033.
Epicyclic change speed gear. Schweinfurter Pracisions Kugel Lager Werke Fichtel & Sachs. 12046.
Process for refining copper. Rockey & Eldridge. 12168.
Devices for relieving compression in internal combustion engines. Sansgter. 12397.
Starters for motor cars driven by internal combustion engines. Parnacott. 12565.
Drilling machines. Mathys. 12584.
Locking nuts. Metall Industrie und Handels Ges. 12778.
Fluid pressure power transmission. Brun. 13489.
Process and apparatus for superheating steam. Prinz zu Lowenstein. 13995.
Acetylene gas appliances. Hind. 14055.
Chucks. Sjostrand. 14897.
Cooling towers. Harrison. 15074.
Means for locking nuts. Poole & Perry. 15820.
Injection of fuel into internal-combustion engines. Müller. 16419.
Valve gear, more especially for high speed engines. Adlerwerke vorm. Heinrich Kleyer Akt. Ges. 16444.
Carburetters for internal combustion engines. Thomson. 16468.
Spiral guided gas holders. Broadhead, and Robert Dempster and Sons, Ltd. 16655.
Shaft bearings. British Thomson Houston Company. 16805.
Apparatus for separating oil from steam. Wischner. 16888.
Machinery for grinding and polishing. Royce, and Rolls Royce, Ltd. 17713.
Inlets of tube mills. Horsfield. 17902.
Rotary engine. McMillan & Carey. 18467.
Process for increasing the yield of chromium in the aluminothermic production of carbon free ferro chromium from chrome iron ore. Th Goldschmidt Akt. Ges. 18671.
Automatic explosion and emergency control apparatus for stop valves. Kerr. 19729.
Rotary engine with electrical power transmission gear. Beldiman. 19787.
Process of recovering and treating sulphurous and the like gases from furnaces. Peniakoff. 21476.
Compression of air and other gases. Aumont. 21837.
Cam gear for internal combustion engines. Rhys. 21999.
Fuel injecting apparatus for internal combustion engines. Pasel. 22617.
Gas producers. Cousin. 23256.
Root's blowers. Jedrusik & Czajkowski. 23348.
Automatic devices for elevators. Harbaugh. 24650.
Piston rings. Campbell. 24745.
Automatic couplers for railway carriages. Willison. 25491.
Reversible propeller. Cribbes & Peterson. 26842.
Chucks. Brown & Bostock. 27262.
High speed tool steel. Stahlwerk Becker Akt Ges. 27838.
Washers or packing for high hydraulic or steam pressures. Laing. 27926.
Method and apparatus for discharging vertical coking chambers. Stettiner Chamotte Fabrik Akt. Ges. vorm. Didier. 27949.
Metal packing rings for stuffing boxes. Huhn. 28156.
Centrifugal pumps and compressors. Akt. Ges. des Maschinenfabriken Escher Wyss et Cie. 28197.
Ball bearings for shafting. Deutsche Kugellager Fabrik Ges. 29697.

1913.

Wrenches. Schroder. 354.
Driving belt with driving pieces or friction blocks. Haltmann. 2151.
Detectors of combustible gases. Philip & Steele. 3002.

ELECTRICAL, 1912.

Means for operating track and conductor points on tramways. Tyrer & Whalley. 5721.
Switch arrangement for electric incandescent lamps. Smith. 5814.
Apparatus for the electrolytic refining of iron. Tischenko. 5855.
Variable speed dynamos for use in starting internal combustion engines. Leitner. 6189.
Systems of electrical distribution. British Thomson Houston Company. 6212.
Electrically controlled lifts or elevators. Rozier. 6304.
Insulating supports for the conductor rails of electric railways. Brook. 6473.
Automatic apparatus for operating electric starting switches. Clatworthy. 6599.
Electric indicating apparatus. Kilroy, and Evershed & Vignoles, Ltd. 6792.
Electric lighting systems for automobiles. Bijur. 6803.
Electric resistance furnace. Ubbelohde. 9203.
Alternating current generators. Shaw, Shaw, & Sharp. 10427.
Machines for making electric incandescent lamp bases. British Thomson Houston Company. 13788.
Devices for adjusting the time of ignition in internal combustion engines provided with magneto electric ignition machines. Bloxham. 17489.
High tension insulators for overhead lines. Fellenberg. 17761.
Electrodes for electrolytic measuring instruments. Hatfield, and Chamberlain & Hookham. 18341.
Two rate electricity meters. Landis & Gyr. 24503.
Thermo electric batteries. Gross. 25372.
Controllers for electric motors. Riley. 25591.
Dry electric batteries. Bohle & "Volta" Commanditgesellschaft fur Elektrische Kleinbeleuchtung. 26699.
Electrical heating apparatus. Byng & Collings. 28542.

Junior Institution of Engineers.—The following papers are down for reading before this Institution: April 11th, at 39, Victoria Street, S.W., paper on "Methods of Regulating and Controlling Working of Electric Accumulators," by Mr. G. C. Allingham; April 18th, at 39, Victoria Street, S.W., paper on "Crude Oil Engines," by Mr. W. A. Tookey; April 23rd, at the Institution of Electrical Engineers, Victoria Embankment, paper on "Modern Developments of Aeroplane Theory," by Mr. Archibald Low, M.A.; April 25th, at 39, Victoria Street, S.W., paper on "Condensing Machinery," by Mr. J. Elliott; May 2nd, at 39, Victoria Street, S.W., paper on "Superintending the Erection of Large Steel-framed Buildings in Quick Time," by Mr. B. B. Tarring.

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WILLIAM H. FOWLER
Wh. Sc., M.Inst.C.E.

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American Locomotive Development.

One of the most important features in the modern development of locomotives is the increase in size and weight necessitated by the continuous demand for increased power. In this country loading gauges and inter rail space are so fixed by the dimensions of tunnels and bridges of crystallised railway practice, that the limits of development may be said to be practically reached. In the United States, engineers are not limited to the same extent by these considerations, and as a result locomotives there have attained mammoth dimensions, and though the boundaries as regards size still leave room for increase, other considerations indicate that the limits of practical development cannot be pushed much further without serious fundamental changes in track construction and methods of firing. The subject does not perhaps directly concern British locomotive engineers, since it deals with matters outside their practice, but the problems are none the less interesting or worthy of note on that account. Some idea of the potentiality of track troubles may be gathered from the fact that loads of 50,000lbs. to 60,000lbs. per driving axle are general, while in some recent engines, we believe it has reached even 70,000lbs. While it does not appear that these loads are directly responsible for fractures in rails of good quality, they do undoubtedly tend to materially increase wear and tear and aggravate any weakness due to initial defects, for the hammer blow of such weights at high speeds is particularly trying, and the question of its diminution is already presenting to American engineers some serious problems in engine design, since high speeds preclude the coupling together of more than three driving axles, and the generation of more power from a given weight, when details are already cut fine, as they often are in American practice, is not easy. The use of special steels and alloys would seem, in this direction, to afford the only means of providing a solution, but progress with these, however, can only be made slowly, and in the light

of experience, the failures of parts may become excessive, and so render the working uneconomical and unreliable. For low speeds these difficulties are not so pronounced, since four-coupled axles are practicable, and, in fact, are used on several roads.

The boiler is, however, the real basis of locomotive power, and the dimensions it has attained have already passed the limits of hand-firing and human endurance. With grates over 10ft. in length—approximating to 100 sq. ft. in area—and coal consumptions of over two tons per hour, some method of mechanical stoking becomes more or less imperative. This particular feature of locomotive development is one with which, of course, we have no experience in this country, and, in fact, the size of British engines would not permit of their application. Even when locomotives are large, the adoption of a mechanical stoker presents problems quite different to those of stationary practice, and much more difficult of practical solution. Necessity is, however, the mother of invention, and for years many ingenious minds in the States have been devoted to the working out of apparatus of this kind, with the result that some half-dozen types are now offered for choice, though from the comparative few in actual service they cannot as yet be said to have passed much beyond the experimental stage, and before any type is adopted generally many improvements will require to be, and doubtless will be, worked out. The principal benefit to be secured by the application of mechanical stoking to large locomotives is the realisation of maximum boiler capacity, thereby supplementing the advantages reaped by superheating, better engine proportions, and other detailed improvements.

An interesting suggestion with respect to what may be termed the "fuel aspect" of locomotive capacity, was made recently by Prof. Goss, of Illinois University*, whose research work in connection with locomotive problems will be familiar to many of our readers. His suggestion appears to have sprung out of some tests and experiments with the Jacob-Schupert firebox,† the construction of which lends itself readily to much greater increase of dimensions than is practicable with the ordinary radial stay construction. It consists in boldly enlarging the firebox, and adopting grates of 20ft. to 25ft. in length—with an area of as much as 150 sq. ft. —and diminishing the rate of combustion so as to diminish the spark losses which, with present blast pressures, is serious and more or less inevitable. His idea, which he suggests only in broad outline, would necessitate, of course, not only mechanical stoking, but material modification of general engine design, owing to the abnormal length of the boiler, and some articulated form with a space of at least 25ft. between the two systems of wheels. The step between the outline of an idea and its working out is, of course, a big one, and when, as in this case, the idea is so far in advance of anything previously attempted, its consummation may seem distant. But American engineers are not daunted by difficulties, and in view of the eminence of the author of the suggestion, and of his opinion that further locomotive development with coal fuel is only possible on the lines proposed, it is pretty certain that serious efforts will be made to put it into practice.

* See "Mechanical Engineer," June 21st, 1912, page 782.
† See "Mechanical Engineer," pages 304 and 339 ante.

Fatal Steam-pipe Explosion.—Shortly after the arrival at Dartmouth, on Sunday last, of the steamship "Simferopol," of the Russian Volunteer Fleet, bound from Libau to Vladivostock, a fatal accident occurred on board. The vessel was going up to the coal hulk when her main steam pipe burst. An assistant engineer was killed and three others injured.

HOW TO IMPROVE THE STATUS OF ENGINEERS AND ENGINEERING.

AT a meeting of the Society of Engineers (Incorporated), held on Monday, April 7th, Mr. William Ransom, A.M.Inst.C.E., read his essay on "How to Improve the Status of Engineers and Engineering, with Special Reference to Consulting Engineers," which was awarded the second prize in the Status Prize Competition last year, no first prize having been awarded. The author pointed out that the civilisation of to-day had become possible only because of the efforts of the engineer, but that the public did not sufficiently appreciate the advantages they had gained or the men whose work had secured those advantages. Engineers had many lessons to learn from the legal and medical professions, both of which excluded unqualified men and exercised a benevolent professional control over their members, and the State should recognise the engineering profession by giving it an official standing equal to that of other professions. The State should require engineering aspirants to pass a qualifying examination, and should give facilities to pupils and assistants for inspecting large engineering works. Admission to the profession required to be carefully guarded, and the number of pupils allowed to an engineer should be regulated by the extent of his practice, while the climax of the period of pupilage should be a State examination. Much more might be done to make examinations of practical value to those who prepared for them, but no other form of test was possible. When State recognition was obtained for engineers, the members of the profession would constitute one great society, amalgamating the existing societies into one body, which should have the control of professional matters and be the mouthpiece of the profession. Such a society would necessarily have sub-sections dealing with special branches of the profession. While the growth of specialisation must be recognised, it was essential for those who were beginning their training for the profession to acquire a sound general scientific knowledge before he began to specialise. The engineer should not be behind his brethren of the legal and medical professions in regard to professional conduct and etiquette, while the society that represents him should maintain a high standard of professional honour, and must have power to enforce its regulations. The State should fix a scale of minimum professional fees. Consulting engineers were comparatively few in number, and on that account the public placed a high value upon their services. They played an important part in forming public opinion on the profession and the ideals they now placed before themselves would make their impress on the younger generation of engineers. The tone of the profession could not be set by the professional societies, but every individual must live up to a high code of professional conduct. The public estimate of the profession was based not on the conduct of the best members but that of the average member, hence the importance of every engineer setting an example of lofty ideals before his staff, his clients, and the public.

THE REGENERATION OF SULPHATED STORAGE CELLS.

THE results of some experiments on the regeneration of sulphated storage cells were given in a paper by Mr. C. W. Bennett and Mr. D. S. Cole, recently presented to the American Electro-chemical Society. During the course of the experiments the authors found, rather by accident than otherwise, that a sulphated grid, when placed in sodium hydroxide solution, became reduced to lead very quickly. In order, therefore, to obtain a sodium hydroxide solution in the pores of the lead plate, electrolysis with sodium sulphate as electrolyte suggested itself at once. The current should be sent through the cell in the direction of charging; sodium hydroxide would be formed at the lead plate, and sulphuric acid at the lead dioxide plate. Thus an alkaline solution would be formed at the cathode and an acid one at the anode. Now, if the electrode potential for the liberation of hydrogen was measured, it would be found that a higher voltage was necessary when an alkaline solution was used than that required for a neutral or acid solution. In the same way a higher voltage was required for the liberation of oxygen in acid solutions. The discharge potentials for hydrogen and

oxygen, respectively, would therefore be increased over those in a straight acid solution. In this way the range of reduction and oxidation would be increased, for a higher voltage could be impressed without the liberation of hydrogen and oxygen. Thus there was a greater tendency to reduce lead sulphate to lead at the lead plate or cathode, and oxidise lead sulphate to lead dioxide at the lead dioxide plate or anode. When this was tried on cells that were uniformly coated with lead sulphate the results were astonishing. Cells with a capacity of one ampere-minute were brought back to their original rated capacity, and in some cases to a capacity over 100 per cent. of the original rating. The concentration of sodium sulphate recommended, which could be varied within wide limits, was 200 grammes of the crystallised salt ($Na_2SO_4 10H_2O$) per litre. The sodium sulphate should fulfil, as regards purity, the requirement for battery acid, *i.e.*, it should be chemically pure. It was not necessary to wash out all of the sodium sulphate; the plates needed only to be dipped once in water. The time of charging in the sodium sulphate solution, for the worst cells, was about 60 hours, at the 8-hour rate. In order to verify these results on a larger scale than had previously been tried, it was thought desirable to treat a battery belonging to the Department of Electrical Engineering, of Sibley College, Cornell University. As a result of this experiment, it was found that: (1) Badly-sulphated cells could be economically regenerated by electrolysis in sodium sulphate solution. (2) The cost need not be greater than 10d. per cell. (3) Allowing 2½d. per kilowatt-hour for power, the increase in the efficiency of the cell would pay for the regeneration in about 90 charges and discharges, or in about three months' daily use.

WROUGHT IRON AND STEEL.

AT a meeting of Staffordshire Iron and Steel Institute, held at the Institute, Dudley, on Saturday last, a paper was read by Mr. David E. Roberts on "The latest developments of the Roe puddling furnaces." Now that steel in its many forms had been commercially used for 30 or 40 years and had been replacing iron in almost every field of activity the test of time was clearly showing, and users were agreeing, that, after all, the old wrought iron for certain purposes was undoubtedly the better article. For such work as chains, buried pipes, fencing, wagon under-frames, steamer decks, roof sheeting, and much exposed structures it had unquestionable advantages. Doubtless pure chemical composition was one feature that safeguarded wrought iron against corrosion, but the real advantage it held over steel in this respect was not so much due to its chemical composition as to its physical characteristics. Several attempts were being made to make soft steel of such a very pure character that it was claimed to hold all the advantages of wrought iron. This material was put largely on the market under the name of "ingot iron," but, although its analysis left nothing to be desired, yet the very fact that it was not finished in a plastic condition prevented it from having the protective influence of the impregnated slag, and, therefore, in the matter of corrosion it was a totally different substance and was not at all comparable with wrought iron. Some authorities had put forward scientific tests that had been made between these substances, "ingot iron" and the real iron, and claimed that these corrosion tests indicated the superiority of the former. It was very questionable, however, whether these accelerated corrosion tests could really be relied upon at all. It was claimed from the experience already gained of the Roe puddling furnaces in operation that not only was the product much cheaper, but that it was improved in character over ordinary puddled iron due to more thorough agitation, working on a hot bottom, and consequently greater uniformity of the mass, less likelihood of laminations when the mass was rolled direct, and more scientific control of the cinder and thereby the character of the product. It was also found that a greater range of pig iron was made possible for a given product.

Boiler Explosion on the ss. "City of Lincoln."—The formal investigation ordered by the Board of Trade to be held in connection with the explosion on board the steamship "City of Lincoln," is fixed for hearing in the Grand Jury Room, St. George's Hall, Liverpool, on Thursday, the 24th inst., at 11 a.m.

THE WORKING OF GAS PRODUCERS.*

BY R. J. DURLEY.

GAS producers differ in design according to the fuel with which they are to be operated and the purpose for which the gas is to be employed. Gas for power purposes, to be used successfully in an internal-combustion engine, must be cleaner and more uniform in composition than is necessary in the case of gas to be used only for fuel or metallurgical work.

The term producer gas is used to denote the mixture of gases obtained by passing air, or a mixture of steam and air, through a body of incandescent solid carbonaceous fuel; coal, coke, peat, or wood are all successfully used. The simplest kind of gas producer is one using a fuel, such as coke, containing little or no volatile combustible matter and supplied only with air. The arrangement of a simple up-draught producer is shown in Fig. 1, and it will be seen to contain a somewhat deep bed of fuel, F, surrounded by a gas tight envelope of plate iron, with proper provision for the supply of air at A, the introduction of fuel at B, and the removal of the resulting gases at G.

The general nature of the actions occurring in such a producer can be readily followed by any one having a slight knowledge of chemistry. With a sufficiently deep bed of fuel

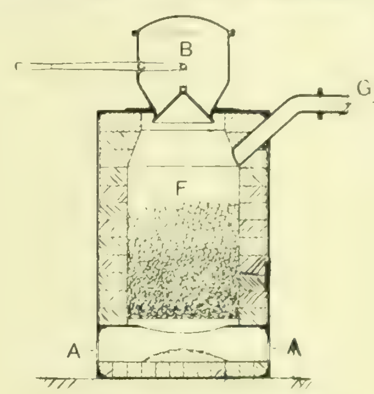


FIG. 1.—SIMPLE GAS PRODUCER.

and a properly adjusted air supply, it will be found that the carbon of the fuel unites with the oxygen of the air to form carbon monoxide (CO), a combustible but poisonous gas, which, if supplied with a further amount of air at a proper temperature, will unite with more oxygen and form carbon dioxide (CO_2), the product of complete combustion of carbon and oxygen. The formation of carbon monoxide in the gas producer thus involves partial combustion of the carbon, and is accompanied by the evolution of only about 30 per cent. of the heat which could be produced by burning the same weight of carbon completely to carbon dioxide. This 30 per cent. is lost, being dissipated by radiation and carried off as sensible heat in the hot producer gas; the balance, about 70 per cent. can be utilised by burning the producer gas with more air. The efficiency of a producer, such as that just described, can, therefore, not exceed about 70 per cent. since a producer of 100 per cent. efficiency is one giving gas which, if burnt, would develop 100 per cent. of the calorific value of the fuel employed. The *efficiency of a producer is*, in fact, the ratio

$$\frac{\text{Calorific value of gas produced}}{\text{Calorific value of fuel consumed}}.$$

It has been found experimentally that the heat produced by burning 1lb. of carbon to carbon monoxide (CO) amounts to about 4,200B.T.U., while if the resulting 2⅓lbs. of carbon monoxide are permitted to unite with a further supply of oxygen so as to produce 3⅔lbs. of carbon dioxide, an additional 10,450B.T.U. is generated. The calorific value of 1lb. of carbon is, therefore, 14,650 B.T.U. when it is completely burnt to carbon dioxide. Hence, as has just been explained, the heat efficiency of the process of formation of carbon monoxide will be $\frac{10,450}{14,650}$ or 71·3 per cent. under ideal or theoretically perfect conditions. In an actual producer of the kind

* From a report published by the Canadian Department of Mines and reproduced from the "Iron Trade Review."

just described even this figure cannot be reached, and it is necessary to adopt some means for utilising a portion of the heat which otherwise would be wasted. This can be done most simply by mixing a proper amount of steam with the air supply.

If steam be passed over incandescent carbon a chemical reaction occurs which splits up the steam into its constituents, hydrogen and oxygen, and the oxygen, under suitable conditions of temperature, unites with the carbon, usually forming both carbon monoxide and carbon dioxide. The gas resulting from this process will, therefore, under ideal conditions, be a mixture of hydrogen, carbon monoxide, and carbon dioxide, the latter in small amount if conditions are favourable. The dissociation of the elements of the steam, however, requires more heat than can be furnished by the combustion of carbon with the resulting oxygen; hence, on the whole, the formation of water gas, by passing steam over red hot carbon, is characterised by the lowering of the producer temperature because of the heat absorbed, and if heat is not supplied from an external source or from some other chemical reaction, the temperature will soon fall so low that the decomposition of the steam ceases. This necessary supply of heat could evidently be furnished by carrying on the formation of air gas in proper quantity, and in many actual gas producers the two processes are in fact carried on simultaneously, the supply of steam being so proportional to that of oxygen that the heat resulting from the formation of air gas by burning a portion of the carbon to carbon monoxide by means of the oxygen of the air, is used up in maintaining the water gas reaction by decomposing the steam. The resulting gas is, therefore, composed of hydrogen, carbon monoxide, and a proportion of carbon-dioxide, the whole diluted by nitrogen and other inert gases derived from the air supply.

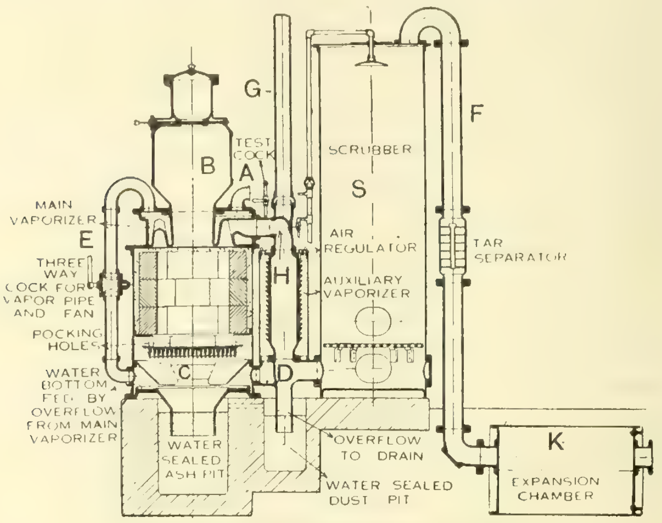


Fig. 2.—Ruston-Proctor Suction Producer.

It should be stated that in the formation of air gas a proportion of carbon dioxide is always formed, in addition to the carbon monoxide, its amount depending upon various circumstances, one of which is the temperature of the producer. Further, should the fuel used be one like anthracite or coke, which contains any compounds of hydrogen and carbon, the resulting gas will probably contain a proportion of volatile or gaseous hydro-carbon compounds. Table I. gives an analysis showing (*a*) the composition of a sample of gas furnished by a producer using anthracite coal and supplied with both air and steam, which may be taken as typical of ordinary producer gas as used for gas engine work; (*b*) the composition of typical air gas in which the supply was air containing only a very small proportion of water vapour and the fuel was coke; (*c*) the composition of water gas made by blowing steam over red hot coke. Anthracite and coke, the fuels used in generating the gases, whose compositions are given in Table I., contain a very large proportion of fixed carbon, typical analysis of these fuels being given in Table II. It is evident thus that if anthracite or coke of good quality is used in a gas producer the resulting gas should contain only a very small proportion of hydrocarbon compounds, and this is, in fact, found to be the case.

When gas is to be generated from fuels such as bituminous coal, which contain a considerable amount of hydrocarbon compounds and give off a large quantity of volatile matter on heating, the problem is a much more difficult one, especially if the gas is to be used for power purposes. This is because the working of the producer itself is more complicated than if non-bituminous fuels are used, and the tarry matters and products of distillation, arising when the coal becomes heated, must be dealt with in such a way as to avoid stoppage in the producer itself, in the pipes, and in the passages and valves of the engines. This aspect of the question is considered later, but it may be said here that by adopting special designs of producer and gas cleaning apparatus coals containing as much as 40 per cent. of volatile matter have been successfully employed for power gas generation.

Table I.—*Composition of Gases by Volume.*

	(a) Producer gas, per cent.	(b) Air gas, per cent.	(c) Water gas, per cent.
Carbon monoxide	27·6	32·6	44·0
Carbon dioxide	3·9	1·4	3·3
Hydrogen	15·3	1·0	48·6
Methane	1·4	—	0·4
Nitrogen, &c.	51·8	65·0	3·7
Total combustible gases	44·3	33·6	93·0
Fuel	Anthracite	Coke	Coke

A sectional view of a Ruston-Proctor gas producer for use with fuel containing little or no volatile matter is given in Fig. 2, from which it will be seen that the arrangement of Fig. 1 is here modified so as to provide for the necessary supply of steam, and the apparatus is intended to be worked as a suction producer in which the engine itself draws into the producer the quantity of air needed for its operation. Slight constructive changes would be needed if the producer were of the pressure type, in which the air is blown in by a fan, or if the draught were maintained by the suction of an exhauster. The steam needed could, of course, be supplied by a separate boiler, but as this would involve additional expense and would require more or less continuous attention, it is usually desirable, especially in small installations, to arrange the producer so as to generate its own steam.

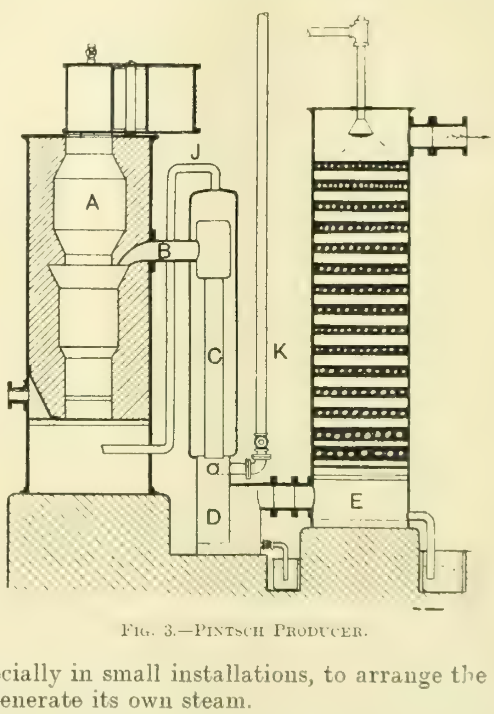


Fig. 3.—Pintsch Producer.

In Fig. 2 the upper part of the producer proper consists of a cast-iron vaporiser or boiler, which is heated by the fuel below, and is so proportioned as to evaporate as nearly as possible the amount of water required to give steam to the air supply. Fuel is introduced through the hopper, B. The air enters at A, passes over the heated water, and carries the required amount of steam along the pipe E, leading to the

space, C, below the grate. The gas leaving the upper part of the producer passes through a water seal, D, and enters the bottom of a wet scrubber, S, consisting of a cylindrical vessel containing a body of loosely packed coke through which water trickles, thus cooling and washing the gas on its upward passage. From the wet or coke scrubber the pipe, F, conducts the gas into an expansion box, K, and then to the engine. For starting the producer, a small hand fan (not shown) and a waste pipe, G, leading to the atmosphere, are provided, so that, when starting, air is blown into the space, C, the cock, H, is opened to the atmosphere, and the producer works under slight pressure, whereas in regular running the pressure in the whole system is slightly less than atmospheric. Suction producers of this type are in use up to about 500 h.p.; larger producers are usually of the pressure type, in which air is supplied by a blower or steam jet, and the whole apparatus is under a plenum.

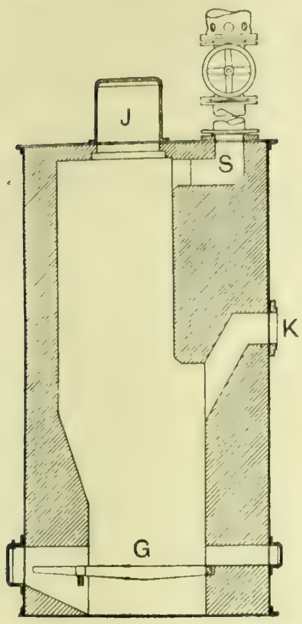


Fig. 4.—Koerting Producer for Lignite Briquettes.

It should be noted that in suction gas producers the vaporiser or boiler is frequently placed in the pipe leading to the scrubber, and not in the producer itself. An apparatus of this kind is shown in Fig. 3, which represents the Pintsch suction producer. Here the hot gas from the fuel bed, leaving the producer by the pipe, B, passes through a vertical tube, C, in what is really a small boiler, fed by a gravity water supply, and discharging steam at atmospheric pressure by the pipe, J, into the space below the grate of the producer. Automatic adjustment of the steam supply is arranged, so as to suit the requirements of the fuel and load. The producer is provided with a dust trap, D, and the usual wet scrubber, E, and its accessories.

Table II.—*Composition of Anthracite and Coke.*

Fuel.	Fixed carbon, Per cent.	Volatile matter, Per cent.	Ash, Per cent.
Anthracite	85·0	8·5	6·5
Coke	89·0	1·3	9·7

For the operation of an anthracite or coke producer, provision must, of course, be made for poking the fire, for the removal of ash and supply of fresh fuel, and for getting rid of any dust or refuse which may be deposited in the pipes or scrubbers. The chief troubles to be guarded against arise from the formation of clinker in the producer, or from gas explosions in the producer or pipes; also there is the possibility of gas poisoning if any leak or opening permits the escape of gas containing carbon monoxide into the producer or engine-room. The term clinker in a gas producer is used to denote the fused ash of the fuel. If the temperature in the incandescent zone of the fuel bed is such that the ash melts as it is formed, there is a tendency for the melted ash or clinker to adhere to the wall of the producer and seriously interferes with the regular working of the apparatus. Sometimes a ring of clinker grows out from the wall of the producer and seriously interferes with the regular downward movement of the fresh fuel which ought to occur as that below is burnt away. In such a case it is necessary to remove the adherent mass by poking. The trouble may evidently be avoided either by using a fuel whose ash has a high melting point, or by working with a low temperature in the fuel bed. The latter result is easily obtained by increasing the proportion of steam in the air supply, but too low a temperature is undesirable, since it is found that with very low producer temperatures the resulting gas will be high in carbon dioxide and low in carbon monoxide; the calorific value of the gas generated will thus be lessened. The usual temperature in the heated zone of a gas producer is about 1,500° to 2,100° Fah.

The risk of gas explosion in a properly operated gas producer plant is very slight. In order to produce an explosive mixture, the gas after leaving the fuel bed must be mixed with air, and this can only occur through leaky joints, valves, or cocks in a suction plant, or by the improper use of openings, such as ash pit, cleaning, or poke hole doors. The pipe system should always be provided with a sufficient number of water seals, like that shown at the bottom of the gas outlet pipe in Fig. 2, so that the effect of a gas explosion in the piping will simply be to blow out the water in one or more of the seals. When cleaning out a scrubber or gas holder, no fire or light should be allowed in the producer house, and all precautions should be taken to avoid possibility of explosion.

Carbon monoxide is the only poisonous constituent of producer gas, but it is inodorous and occurs in sufficient amount to render the gas dangerous to human life if inhaled. Every care should, therefore, be taken to guard against leakage, and the producer house must be well-ventilated. When cleaning is to be done it is very imprudent to enter a scrubber, gas holder, or any part of the installation until it is completely cleared of gas, and has been blown out with fresh air. Again, in starting a suction plant care must be taken that the engine is not in such a position that both gas and air inlet valves are open, as in this case gas might possibly be driven through the producer by the starting fan and thence into the engine-room. Unburnt gas should not be allowed to escape from test cocks or other orifices into the producer or engine-room. On account of the fact that with a suction producer the pressure within the gas system is less than that of the atmosphere, any leakage occurring when the engine is working will be from the air into the producer or piping. With a pressure plant, however, the leakage is outwards, and for this reason such plants require more care to guard against possible leaks.

The efficiency reached by well-designed gas producers in practice is high. Well-designed installations working with suitable fuel have produced gas whose calorific value is as much as 85 per cent. of that of the fuel burnt, even in small sizes. It is probable, however, that in every-day working the efficiency of the ordinary suction producer does not exceed 75 per cent. to 80 per cent. and most installations working

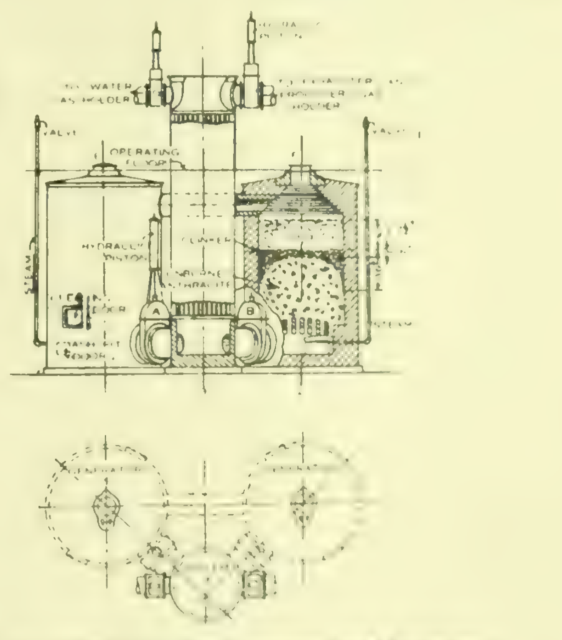


Fig. 5.—Loomis-Pettibone Twin [illegible]

with bituminous coal show a considerably lower efficiency than this.

It should be noted that when producer gas containing hydrogen or hydrocarbon compounds is burnt, the heat given up by the products of combustion is greater if the steam formed is condensed than if the steam is not so condensed, because of the relatively large amount of heat given out by

each pound of steam in being turned to water. When speaking of the calorific value of such a gas, it is, therefore, necessary to know whether the higher value, allowing for the condensation of any steam formed, or the lower, or effective value is meant. The two quantities often differ by as much as 10 per cent. It seems right to take the lower value in gas producer work, since the products of combustion are always above 212° Fah. when they leave the engine, and the steam they contain, therefore, is not condensed.

Table III.—*Composition of Typical Gases from Bituminous Coal.*

Type of Producer	R. D. Wood. Per cent.	Westinghouse. Per cent.	Mond. Per cent.
Fuel:—			
Moisture	4·21	1·39	2·0
Fixed carbon	53·16	74·28	65·0
Volatile matter	35·41	16·01	27·0
Ash	7·22	8·32	6·0
Gas (per cent. by volume):—			
Carbon monoxide	23·4	18·1	15·3
Carbon dioxide	7·9	7·9	13·2
Hydrogen	17·1	12·6	19·35
Methane	2·1	2·6	3·85
Oxygen		0·5	
Nitrogen, &c.	49·5	58·3	48·3
Calorific value (lower) B.T.U.:			
Per cubic foot	150·0	117·8	141·7

Gas for use in gas engines must be clean, that is, practically free from dust or tarry matter which will cause obstruction in the passages or undue wear of the working parts of the engine. Such gas should be delivered to the engine at as low a temperature and at as high a density as possible, so that the engine may take in a charge having the greatest possible heat value. The gas should be uniform in quality and uninterrupted in supply, whatever the rate at which the producer is worked, and the operation of the producer plant should involve but little supervision and manual labour on the part of the attendants.

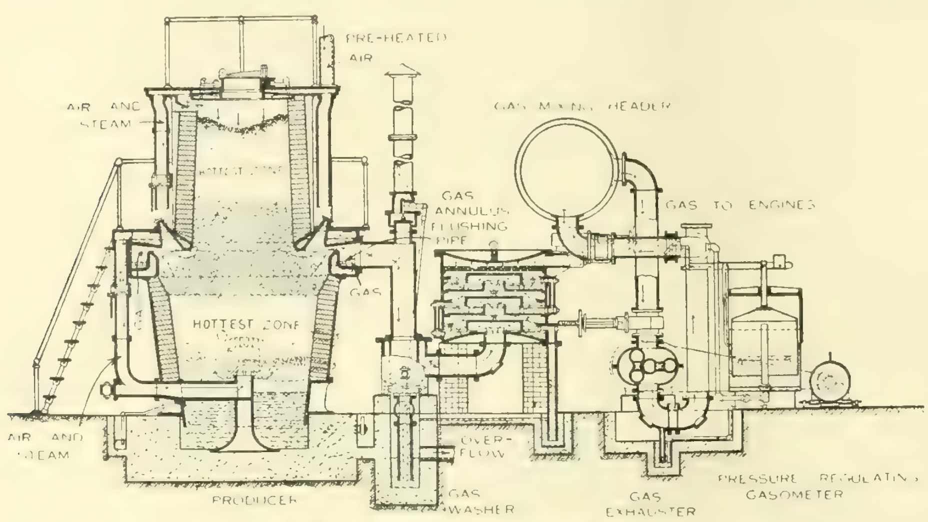


Fig. 6.—Westinghouse Double-zone Producer and Auxiliaries.

Gas producers using bituminous coals have been successfully used for industrial purposes, such as cement burning, steel melting, and the like, since the introduction of the Siemens producer and furnace in 1861, but such producers are usually of considerable size, and furnish gas which is neither clean nor cool. Freedom from tar, and low temperature of gas, are qualities of little or no advantage for furnace work; and fuel gas producers are, therefore, simpler and less difficult in operation than is the case with producers supplying gas for power purposes. A coal may be capable of giving satisfactory results in a large fuel gas producer, and may, nevertheless, give trouble when burnt in a producer furnishing gas for power purposes, especially if the producer is a small one. Fuel gas producers will not be discussed here, but the construction and operation of a few leading types of power gas producers will be described, in order to illustrate the special difficulties involved in the use of bituminous fuels. Such fuels form the major part of the world's fuel supply, and power gas plants must be capable of utilising bituminous coals if they are to compete successfully with steam plants under any but exceptional circumstances. The composition of certain typical gases made from bituminous coal for power purposes is shown in Table III.

If attempts are made to use bituminous coal in producers of such types as are shown in Figs. 1, 2, and 3, the first effect of the introduction of a portion of fresh fuel is that a quantity of the volatile matter is driven off by the heat of the already incandescent fuel bed. The resulting gas is then charged with hydrocarbons, the products of partial distillation of the fresh fuel, as well as with dust arising from the ash of the fuel bed. The tarry matter and dust are partly deposited in the pipe system, and partly removed in the scrubber, which rapidly becomes clogged, but a large amount of objectionable material passes over to the engine, where it soon makes its presence manifest by obstructing the ports and passages, and especially the gas and air valves, so that in a short time the engine ceases to work.

If the bituminous coal employed is of a caking quality the fresh fuel will tend to form a more or less solid layer adhering to the walls of the producer, and permitting the formation of a hollow space as the rest of the fuel burns away below. This layer has to be broken down by poking, a process which disturbs the regular operation of the producer, and is liable to cause rapid changes in the quality and composition of the gas generated, even if it does not render the supply insufficient for the engine. The resistance of the fuel bed to the passage of the gas will also change, and this change will be shown by an increase or diminution of the pressure in the producer and pipe system. In fact, it will be found that an ordinary suction producer equipment which will work perfectly with coke or anthracite fails entirely when tried with bituminous coal, even of non-caking quality. Difficulty from the sticking or hanging of the fuel bed will, of course, be more serious in a small producer than in a large one, for if the producer is of sufficiently large diameter the fuel layers will tend to break down under their own weight without the use of the poker.

Successful power gas producers for bituminous coal must, therefore, provide means for: (1) Destroying or removing the tarry matter arising from the fresh fuel charged. (2) Insuring a uniform downward movement of the charge as the fuel is consumed, without excessive manual labour, thus obtaining continuous and uniform quality of gas. (3) Avoiding the loss arising from unburnt carbon in the refuse. (4) Removing refuse without disturbing the operation of the producer.

The methods by which these ends have been more or less completely attained in actual producers will be seen from the descriptions which follow. The products of distillation from bituminous coal, wood, peat, or other non-anthracite fuel contains various hydrocarbon compounds, which tend to break up into simpler forms, chiefly methane or marsh gas (CH_4), when heated to a temperature corresponding to a bright red heat, this process being often accompanied by the deposition of carbon in the form of lamp black or soot. Hence, if the vapour arising from the fresh fuel in a bituminous producer be drawn through the most highly heated zone of that or of a second producer, the whole or the greater part of the tar will be decomposed or burnt and further difficulty avoided unless the lamp black gives trouble. The only other alternative is to remove the tar by some kind of washing or cleaning process applied to the gas after it leaves the producer.

The Koerting producer, Fig. 4, is designed for use with briquettes made from lignite, and may be taken as an example

of the type in which the tarry matter is destroyed by exposure to a high temperature within the producer. This apparatus is similar in general principle to a producer patented by Dowson in 1903, and consists of a vertical body, 8ft. or 10ft. in height, arranged as shown, with a grate, G, at the bottom, and a gas outlet, K, about half-way up. Air is admitted both at the top and bottom of the producer, and when running on lignite which contains from 15 per cent. to 30 per cent. of moisture, good gas can be obtained with fair efficiency without the admission of additional steam. The gas outlet is so formed that as much as possible of the air entering at the fuel inlet, J, must pass through the heated zone of the fuel before reaching K. A passage, S, which leads from the top of the producer to the atmosphere, is used for starting, and is closed by a valve during regular running. Provision is made for judging the condition of the fire and for poking, as required, by means of proper sight holes and poke holes. The position of the zone of highest temperature can be regulated by varying the relative amounts of air admitted at the top and bottom openings, in such a manner that the products of distillation from the freshly charged fuel are properly decomposed. The lower portion of the producer when working well contains only coked fuel resting on a bed of ash. The whole apparatus may be regarded as a combination of the so-called up-draught and down-draught systems, the passage of the gases being downwards in the upper and upwards in the lower portion. Such a producer would probably not work equally well with caking bituminous coal, as this fuel sticks or hangs in the producer much more than lignite, and poking in a deep producer of comparatively small diameter is not easy.

A producer plant in which the tar is decomposed in a second separate bed of hot fuel is shown in Fig. 5, which represents the Loomis-Pettibone system. In this arrangement two producers or generators, connected at the top, have valves, A and B, leading from the spaces beneath the grates to a boiler or vaporiser. From the top the vaporiser valves, C and D, conduct the cooled gas to either of two gas holders. Fuel is introduced through the hoppers, E and F. The producers are worked in such a way that the products of distillation from the generator that has been coaled have to pass through the hot coked fuel in the other generator. There are several ways of doing this. One method is to work the two generators in parallel, with down-draught, supplying air only, until the temperature rises sufficiently. During this period, the tar from the top of each producer is decomposed in its own heated zone of coked fuel. The valves are then manipulated so that on supplying steam, without any air, to the base of producer No. 1, for example, and thus running it for water gas with up-draught, all gases distilled pass downwards through producer No. 2 and are there freed from tar. During this water-gas run, the temperature in both producers will fall, as the reactions occurring absorb heat instead of developing it, and the water gas produced, which is rich in hydrogen, is usually led to a separate gas holder. When the action has proceeded sufficiently, steam is shut off and air is admitted to both producers, which are worked down-draught as before, so that an air-gas run is made during which the producer temperatures rise, but will evidently be higher in No. 2 than in No. 1 where the water-gas has been made. A second water-gas run is then made, but this time the steam is supplied to the base of No. 2 while the gases pass downwards through No. 1 where the tar is dealt with. Another air blow follows, and the process is repeated indefinitely. Fuel can be charged into either producer while it is working with open top during the air-blow period. Installations of this type have given excellent results, but there is often some difficulty in effecting the proper removal of ash and clinker without interference with continuous operation, and close attention is required to maintain the uniform quality of gas and regular sequence of operations. The gas produced from bituminous coal is, however, of good quality, and such plants are capable of economic working and good efficiency.

As an example of another arrangement for dealing with bituminous coal by destroying tar, the Westinghouse double-zone producer, introduced in 1909, may be selected. This apparatus, like the Koerting producer, is generally similar in principle to the Dowson producer of 1903, but contains means for generating the steam it requires. It has no grate, the refuse being removed through a water seal at the base, and the plant includes many novel accessories and features of construction. The producer is shown in Fig. 6, and from which it will be seen that the cast iron vaporiser, containing the gas outlet passage and a series of poke holes, divides the producer into an upper and a lower portion of different diameters. An air inlet pipe admits air to the steam space of the vaporiser, and vapour pipes, provided with supplementary air admission cocks, lead respectively to the spaces at the top of the upper portion of the producer and to the ash bed just above the water seal. Air and steam in any desired mixture can, therefore, be supplied to the fuel bed either at top or bottom, or at both, and the gas produced is drawn off by an exhauster from the central zone to the gas holder, if used, and engine. Sight holes enable the operator to judge of the condition and location of his fire. Toward the middle level of the producer the fuel is at a lower temperature, while the coke is completely burnt and another zone of combustion occurs near the bottom of the lower part of the producer. In connection with this make of producer, a gas-washer of special type designed for the removal of dust, a mixing header, and a special pressure regulator are employed.

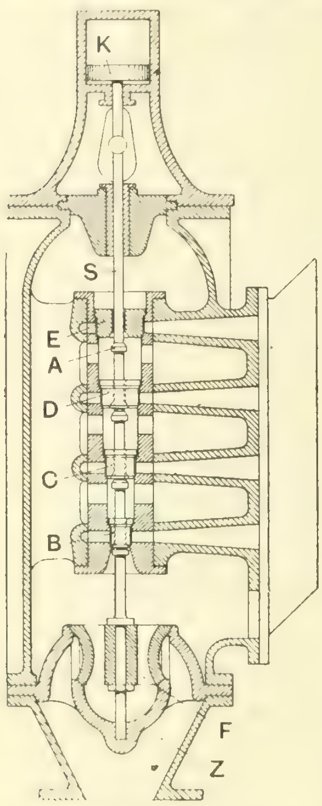
The producers so far described are of the type in which the tarry matter is destroyed by exposure to a high temperature or burnt by a special air supply. Many successful power-gas plants, however, are in use in which the tar is removed from the gas, together with the dust, by power-driven washing and cleaning apparatus. Probably the largest and most highly specialised power-gas installations now at work are those using the Mond process, in which the gas is mechanically cleaned, and this system is of considerable interest, especially as provision can be made for recovering certain of the by-products, such as ammonium sulphate, which are of commercial value. The Mond producer is of the up-draught type with a water seated bottom. It is worked under slight pressure from a blower, and the entering air is mixed with a large amount of steam (about 2½ times the weight of coal burnt), with the object of keeping down the producer temperature, so that any ammonia formed may be recovered and there may be no trouble from clinker. The hot gas leaving the generator is, therefore, mixed with much undecomposed steam, and this mixture gives up its heat in a regenerator to the incoming blast. The gas is then passed through a mechanical washer, and enters special cooling towers where the ammonia is abstracted. Ammonia recovery is not usually practised in plants burning less than 30 tons per day, and the system as a whole is not easily applicable to small powers.

CONTROLLING VALVES FOR STEAM TURBINES.

It is important that the steam admission of the first rotor of a turbine should be automatically adjusted to the existing load on the machine, so that the steam pressure in front of the high-pressure nozzles may remain at the same degree also at small load, and that the whole drop of pressure may be used for output of energy. In order to attain this object, constructions have been proposed having piston valves and also having single-seated and double-seated valves. The arrangement shown in the accompanying sectional views, patented by Bergmann Electric Works Company, Oudenarder Strasse, 23/32, Berlin, N., has, it is claimed, several advantages over existing designs. It consists of double-seated valves moving with sufficient play in a cylinder, in such a manner that only the lower seats of the valves effect the control, while the upper seats maintain, throughout the whole length of the stroke, a uniform passage between themselves and the wall of the cylinder. The upper part of the valve body, therefore, operates to a certain extent as a piston, upon which, in consequence of the difference of dimensions between the upper and the lower valve seats, there is an excess of steam pressure in the direction for closing the valve. Each of the valves controls the admission of steam to a nozzle or to a group of nozzles, the diameters of the several seats, as shown in the accompanying drawing, which is an axial section through the controller, increasing from valve B to valve E successively, so that all the valves,

B, C, D, and E can be raised together with the valve spindle from the cylindrical casing. Between the spindle and the body of the valve there is sufficient play to avoid contact with each other. The valve is lifted by a collar on the spindle, and the valve is securely closed by joint action of its weight and the excess of steam pressure in the direction for closing. The excess of steam pressure increases continuously as the valve approaches the closing position, which is of importance for obtaining a satisfactory tightness.

The mode of control is as follows: The governor adjusts the oil-driven piston K. This piston is connected with the spindle S. The latter carries a series of collars A, which serve as bearing surfaces for the several controlling valves, B, C, D, and E, so that these valves can be raised and lowered in succession by the movements of the piston K. The collars are conically formed, and, when they are raised, enter into corresponding cavities in the valves, whereby the latter are exactly centred on the spindle, when they are lifted from their seats, and can move freely during the whole stroke. To ensure satisfactory working when the machine is running light there is inserted a double-seated main valve F. The steam entering through the inlet Z into the steam chamber must first pass this main valve. The dimensions of this valve are so selected that the free cross-section when it is open increases about four times as rapidly as the free cross-section of the several controlling valves, so that this valve throttles the leakage steam only in the lowest position, and at all events only throttles the steam at the first group of nozzles; while at high loads, and therefore with longer stroke, there is no longer any throttling by this main valve. By this arrangement it is ensured with certainty that even should there be an accidental leak through the several controlling valves, racing of the machine is avoided without necessity for loss owing to throttling at higher loads. The first valve B begins to open as soon as throttling substantially ceases at valve F, that is to say, when the pressure is the same in front of and behind the valve. The valves C, D, &c., close in succession, so that the next succeeding valve always takes up the control as soon as the preceding one has opened to its full extent. In this manner it is claimed that a simple and continuously-operating controlling device is obtained, all loss through throttling being avoided, and there is a considerable decrease in the consumption of steam at low loads as compared with simple throttling.



Controlling Valves for Steam Turbines.

The Incorporated Municipal Electrical Association.—The 18th annual convention of this Association will be held in London from June 17th to June 21st next. The convention will be opened at 10 a.m. on Tuesday, June 17th, in the hall of the Institution of Electrical Engineers, when an address will be delivered by the ex-president, Mr. C. E. C. Shawfield, and a paper on "Prime Movers" will be read by Dr. Ferranti. In the afternoon visits will be made to the West Ham and Deptford electricity works. On the following day a discussion will be held in the hall of the Institution of Electrical Engineers in the morning, and Lots Road power station will be visited in the afternoon. The annual dinner will be held at the Hotel Cecil in the evening. On June 19th a visit will be paid to Kingston-upon-Thames, and papers on "Electric Vehicles," by Messrs. Seabrook, Watson, and Mitchell, and on "Air Filtration," by Mr. J. Christie, will be read.

SOME EFFECTS OF SUPERHEATING AND FEED-WATER HEATING ON LOCOMOTIVE WORKING.*

BY F. H. TREVITHICK AND P. J. COWAN.

(*Concluded from page 372.*)

Appendix I.—The Development of the Heaters.

In the heater systems developed on the Egyptian State Railways the principle has been followed throughout of compelling all the waste gases from the boiler to pass over the heating surface of the smokebox heater. The smokebox is virtually divided into two by the heater, the smokebox compartment proper, and another section beyond the heater, which may be termed the blast chamber, communicating with the chimney. The blast ejects into this latter chamber, and draws the gases through the heater tubes. Table X. illustrates some of the steps in the evolution.

The first of the heaters mentioned below was composed of two large ring-shaped shells, set one within the other, Figs. 17-19. The water flowed successively round a $\frac{3}{4}$in. space in both heaters before passing to the boiler. Plating, fixed to the inner shell and carried back to the smokebox tube-plate, enveloped the tube area. The blast-pipe was carried up through this plating to the base of the chimney, the gases being drawn forward from the tube-plate towards the smokebox door, then back through the annular space between the shells, and sent up the chimney. This was a cumbersome apparatus of small heating surface. In No. 2 (Table X.) the annular space was transformed into tube space, Figs. 20-23. Subsequently a much higher ratio of heating surface to weight was secured, by adopting small drums containing small tubes (Nos. 3 and 4, Table X., and Figs. 24 to 32).

Table X.—*Development of the Smoke-box Heaters.*

		Sq. ft.	
1	Annular Shell Heater	3·53	of heating surface per 1 cwt.
2	Annular Tubular Heater	5·8	of heating surface per 1 cwt.
3	Twin Drum Heater	24	of heating surface per 1 cwt.
4	Single Drum Tubular Heater	36	of heating surface per 1 cwt.

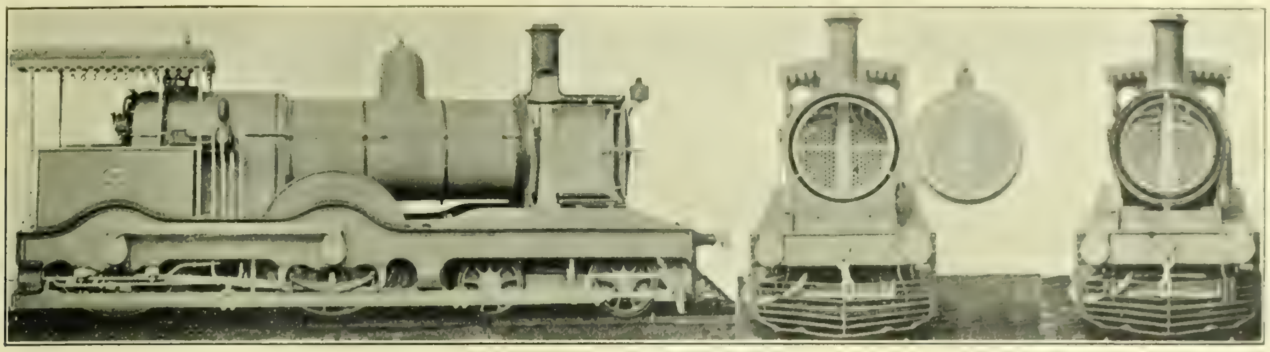
A heater of comparatively high efficiency may thus be obtained. The design possesses two valuable features of equal importance to the success of waste gas heating: (1) The boiler tube-plate is not obstructed; (2) the best tube proportions for the heater may be adopted without regard to limitations of a purely practical character imposed by the boiler. The utmost amount of heat may thus be abstracted from the gases, a result impossible with a tubular heater in the barrel, when the size of the heater tubes is determined by questions of rodding, retubing of the barrel, &c. For heating purposes, long and relatively small tubes are the most effective, and, for a given length, a heater with small tubes is more efficient than one limited to large tubes. Moreover, in the small heater, circulation is more rapid and the transmission greater. If the boiler tubes be shortened in order, as is sometimes done, to provide space for the heater, their efficiency is reduced. The resultant lower boiler efficiency must be made good in the engine before any net gain can be derived from the use of the heater. A small heater with small tubes, combined with a normal boiler barrel, is thus better than a large but short heater with large tubes and a shortened boiler barrel, especially when approximately similar temperatures may be obtained with both. From the practical point there is no comparison between the two, the smaller heater interfering in no way with work on the boiler.

The exhaust heaters have been of the tubular type. An early form is illustrated in Figs. 17-19. In later arrangements the exhaust heaters were placed on either side of the smokebox on the running board, and consisted of long cylindrical shells fitted with tube-plates and small tubes. The water circulated outside, and the steam through, the tubes. The pump exhaust heater was similar, but arranged vertically below the pump, on the suction side. The feed passes in series through the two main exhaust heaters, which are supplied by 3in. branch pipes from the exhaust cavity of the cylinder casting.

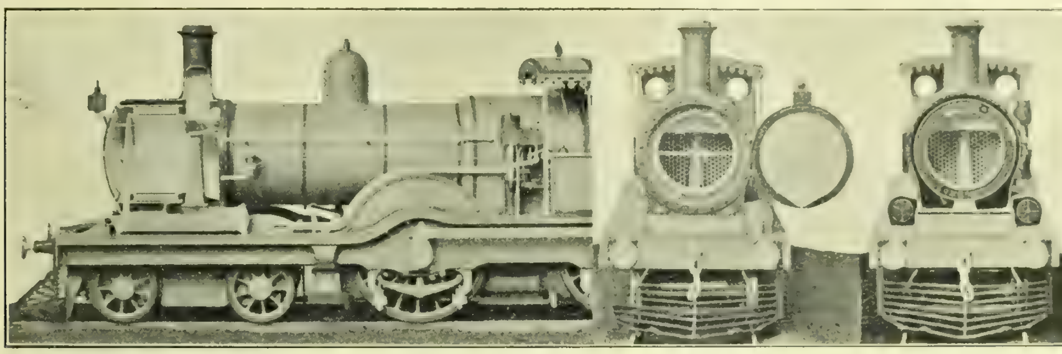
* Paper read before the Institution of Mechanical Engineers, March 14th, 1913.

By means of diaphragms inserted among the tubes, it is made to traverse the length two or more times.

The Egyptian State Railways engines of the 695-724 class, which are chiefly referred to in the paper, are of the 4—4—0 type, having 18in. by 26in. cylinders, a boiler pressure of 180lbs. per square inch, and 6ft. 3in. driving wheels. The grate area is 23·74 sq. ft., and they have a heating surface of 1,108·4 sq. ft. provided by the tubes, and 141·1 in the firebox.



FIGS. 17, 18 AND 19.—HIGH DEGREE FEED-WATER HEATING SYSTEM; SMOKEBOX HEATER NO. 1 (Table 10).



FIGS. 20, 21 AND 22.—HIGH DEGREE FEED-WATER SYSTEM, TYPE A (See Appendix I). SMOKEBOX HEATER, NO. 2 (Table 10).

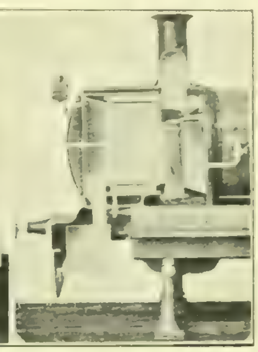
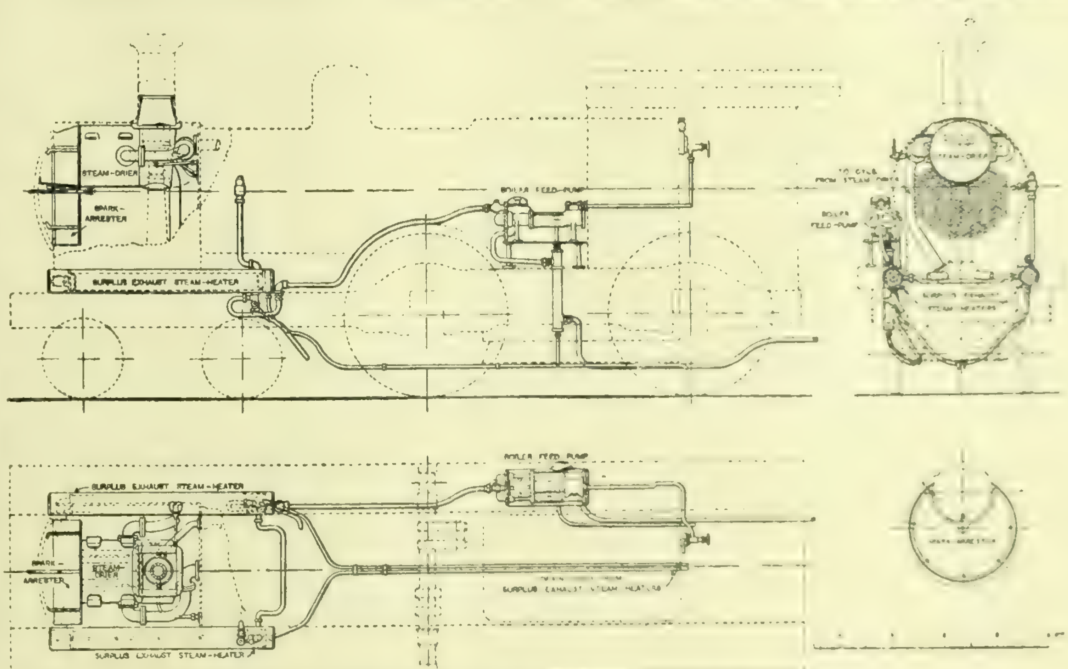


FIG. 23.—SMOKEBOX WITH HEATER NO. 2 (Table 10), AND SPARK ARRESTER AND ASH HOPPER.

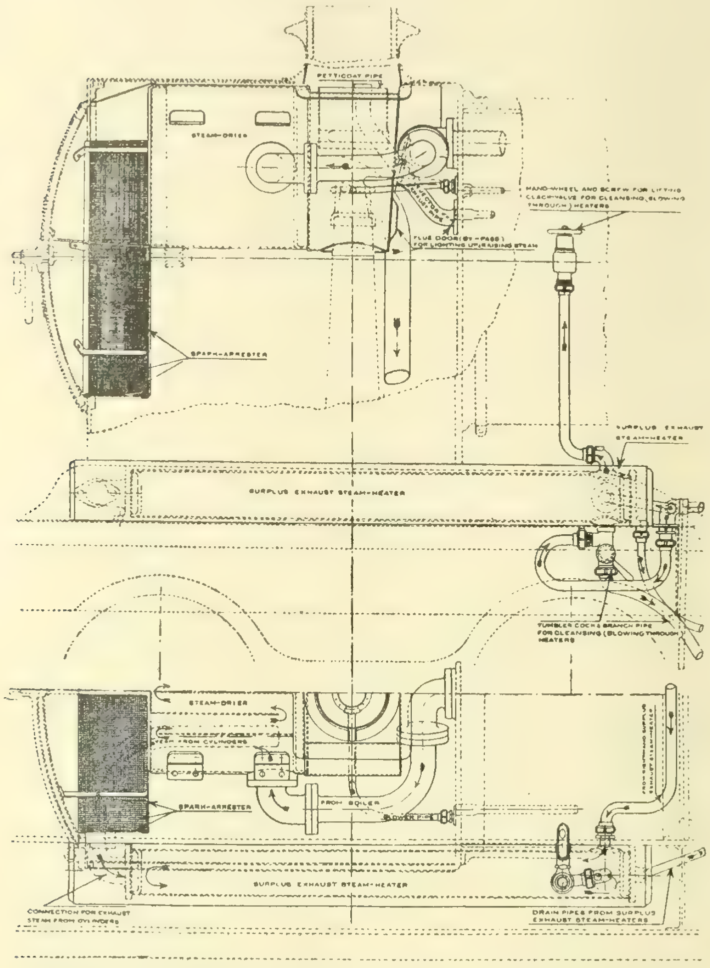
Type A. Installation for High Degree Feed-water Heating. (Engine No. 711).—This class of installation is illustrated in Figs. 20-23. It comprised pump feed and (1) a pump exhaust heater, (2) two main exhaust heaters, and (3) a large heater in the smokebox, all arranged in series. The smokebox heater is shown in longitudinal section in Figs. 20 and 23. The shaped ring-tube plates were 1ft. 11in. apart. It contained 671 tubes, the majority being $\frac{1}{2}$in. in internal diamter. The boiler-tube area was again enclosed as described previously, and the blast, arranged in the outer space thus formed, drew the gases of combustion forward and then back through the heater tubes. Fig. 23 shows a form of spark arrester and ash hopper which gave the best results. This heater provided about 248 sq. ft. of heating surface, and the exhaust heaters altogether about 147 sq. ft. Feed temperatures (exceeded with later patterns) of 270° Fah. were obtained, with temperatures of even 360° Fah. for short spells after stops. This design was cumbersome and was not adhered to.



FIGS. 24--27.—EXHAUST FEED-HEATING AND WASTE GAS SUPERHEATING SYSTEM, TYPE B (See Appendix I). SMOKEBOX HEATER NO. 4 (Table 10). See also Figs. 28-32.

Type B. Installation giving moderate degree Feed heating and moderate Superheating, or high degree Feed heating only. (Engine No. 706.)—The installation shown in Figs. 24 to 32 is simple and cheap to install. It includes a pump on the driver's side, a small pump exhaust heater and two main exhaust heaters, and a smokebox heater in the form of a single drum in the upper part of the smokebox. With simple alterations, the latter can be adapted either for feed-water heating or for superheating. On the Egyptian State Railways it proved, on the whole, most advantageous when used as a superheater. Heaters fitted to the 706 class of engine contain 943 tubes of $\frac{1}{2}$in. bore, and have 322 sq. ft. of heating surface. Inside, baffles are provided butting alternately against the opposite tube-plates. These, and the restricted volume, ensure rapid circulation.

The concentration of the heating surface in such a drum overcomes many of the objections usually raised against smokebox heaters, and also enables effective provision to be made for the enclosed blast. The blast-pipe top is enclosed in a hood or uptake which, depending from the chimney, envelops completely the back tube-plate of the heater. A



Figs. 28 & 29. Exhaust Feed-heating and Waste Gas Superheating System, Type B (Appendix I.) (For general arrangement see Figs. 24-27.)

short petticoat pipe inside the hood distributes the effect of the blast evenly over the tubes, and also makes it possible to use a blast-pipe which does not protrude far into the uptake. The uptake itself and all heater tubes thus become self-clearing. At the back of the uptake is fitted a flue door to facilitate lighting up. The blower and ejector discharge are arranged within the uptake.

The spark arrester forms a special feature of this installation. Effective spark arresting is essential in countries such as Egypt, where conditions are often extremely favourable to fire, and the climate favours the transport of goods in open wagons, unprotected. The standard locomotives, Fig. 33, on the Egyptian State Railways are all fitted with spark arresters, and with large smokeboxes, which are found to be a necessary accompaniment of an efficient arrester, for which ample area is necessary, in order to prevent the netting becoming blind during working, and impeding the draught. With large smokeboxes ample area may be had, and all risk of the engine failing to steam removed. In some of the heater engines of the Egyptian State Railways the netting extends across the upper part of the smokebox, just below the heater, the screen being completed by netting attached vertically to the door. A more convenient form is shown in Figs. 24 to 32. This arrester is like a sieve with both sides and end of wire mesh, fixed wholly to the door, Fig. 30, with which it opens, leaving the interior clear. The netting is shaped to fit round the heater, the tubeplate of which remains uncovered. The heater itself assists in quenching such live sparks as may get through the netting. Their passage through the small tubes, and the intimate contact into which they are brought with the exhaust, in the small blast chamber, is very effective in rendering the sparks innocuous, and there is a marked absence of glowing cinders ejected from the chimney.

Waste gas heaters, such as those in Figs. 24 to 30, give superheat of 85°-90° Fah. on 180lbs. per square inch boiler pressure, but heaters have been used giving rather more than this (90°-100°), taken at the root of the steam pipe near the steam chest. Used in this way, this heater has been employed in combination with feed-water exhaust steam heaters giving temperatures of about 210° Fah. When used for feed-heating,

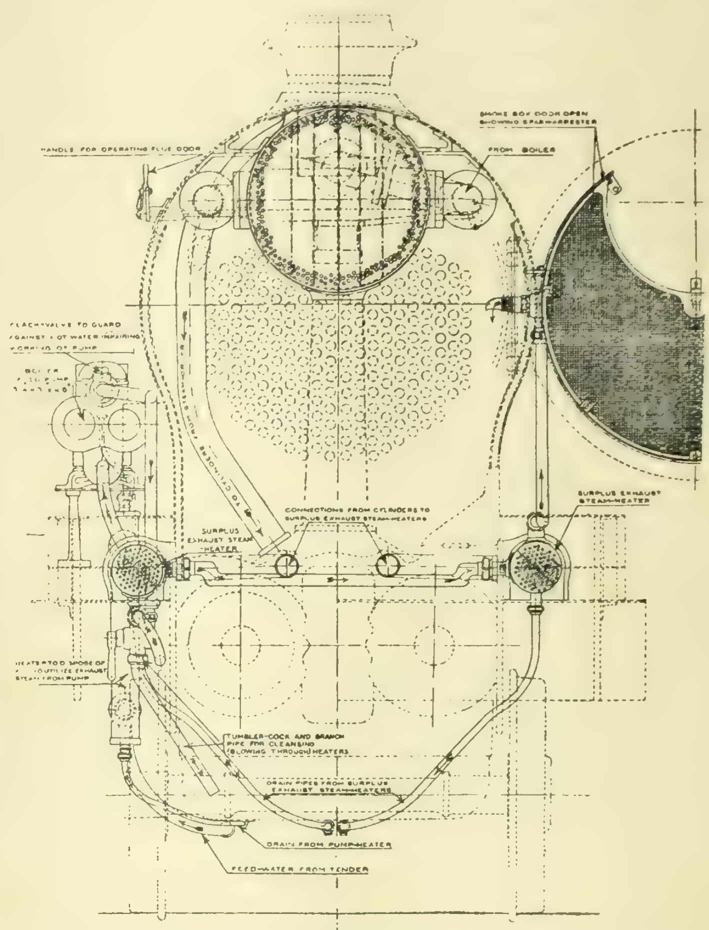
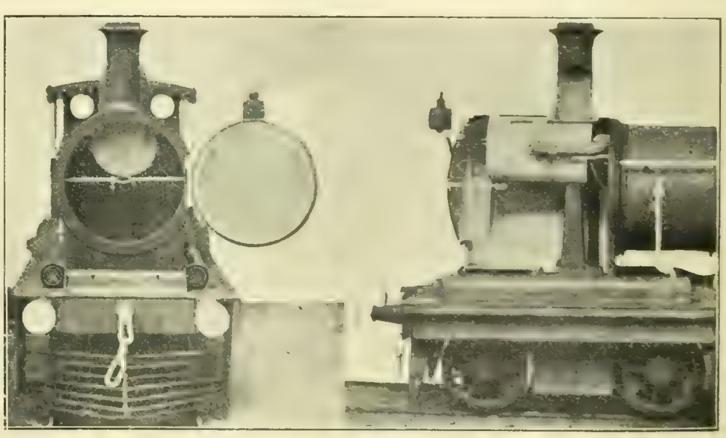


Fig. 30.—Exhaust Feed-heating and Waste Gas Superheating System. Type B (Appendix I.) (For general arrangement see Figs. 24-27.)

in conjunction with the exhaust steam heaters, feed temperatures above 280° Fah. are obtained.

Type C. Installation for High Degree Superheating and High Degree Feed-water Heating. (Engine No. 712.)—In this case an engine was first converted into a smoke-tube super-



Figs. 31 & 32. Exhaust Feed-heating and Waste Gas Superheating System. Type B (Appendix I.)

heater engine, to the recommendations of the Schmidt Superheating Company, of Wilhelmshohe, and with parts furnished by Messrs. Henschel & Sohn, of Cassel, the original builder of this class of engines. In compliance with Messrs. Schmidt's advice the engine was rebuilt with piston valves, in place of the Egyptian State Railways standard slide-valve cylinders. The superheater installation gave temperatures rather below usual European practice. At 180lbs. pressure the superheat

varied between 200° and 230° Fah. according to load. The engine so fitted, and having the advantage of piston valves, proved to be more economical on coal than ordinary sister engines by about 29·8 per cent.

The further addition of the feed-heating system was carried out as in Figs. 34 to 38. The pump was on the driver's side with its exhaust heater below it. Two main cylinder exhaust heaters, 7ft. long and 7in. diam., were placed alongside the smokebox. They each contain 82 tubes, and provide together 150 sq. ft. of heating surface. In the smokebox, two horizontal drum heaters were placed with their axis across the smokebox. Each contained 465 tubes, and together they provided heating surface of 339 sq. ft. They were connected by the cross limb of a large inverted tee-shaped uptake continuous with the chimney. The general arrangement of blast-pipe, petticoat, side doors, spark arresters, side hoppers, &c., are clearly shown in Figs. 34 to 38. At the elbow of the blast-pipe, branch connections led exhaust steam off to the main exhaust heaters. On the unbolting of two pipe connections to each heater, the latter could be withdrawn through the side doors. The sieve-shaped netting spark arresters were fixed to the side doors. The side ash hoppers were fitted with doors and sloping floors. The water heaters were all connected in series. A flue door was provided in the uptake. The resultant effect of this installation is rather complex. Feed temperatures of over 290° Fah. were obtained, but not with the original degree of superheat, for reasons already explained.

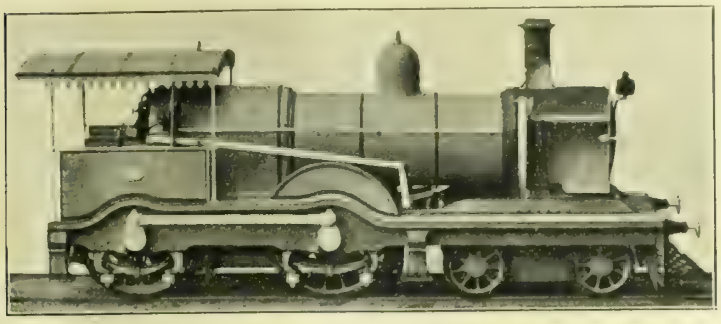
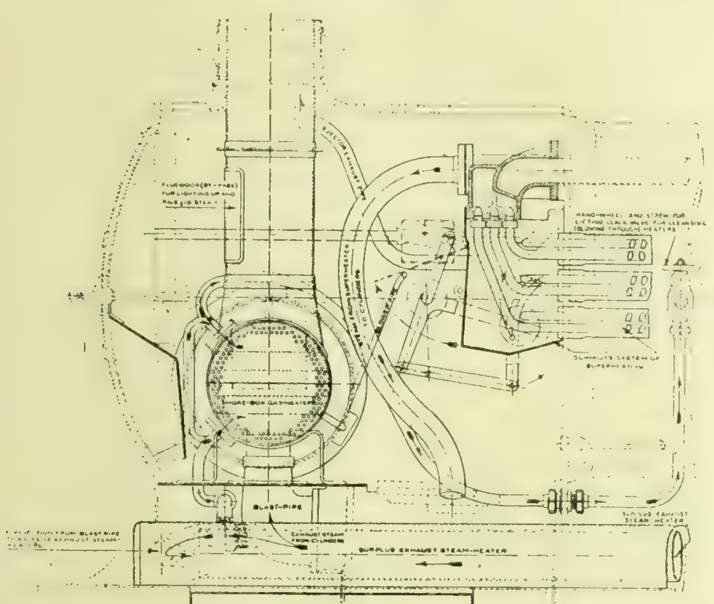


Fig. 33.—Non-heater Engine with Standard Smokebox.



Figs. 34 and 35.—High Degree Feed-water Heating and High Degree Superheating System, Type C (Appendix I.) See also Figs. 37 and 38.

Type D. Installation for High Degree Superheating and High Degree Feed-water Heating. (Engine No. 712.)—Fig. 39 shows a later device fitted to Engine 712, in order to remove as much apparatus as possible from the smokebox. The smokebox heater is carried by a door plate, and the blast chamber and chimney are removed to the forward end of the heater. The flow of the gases is direct, and less resistance is offered to their passage, tubes of $\frac{3}{4}$in. bore having been used in this case. The draught is lighter than in the other designs. On opening the smokebox door, the heater and chimney swing clear. No trouble has been met with in making the necessary joints, &c., for this arrangement, which therefore appears to have advantages over the installation Type C, above described.

Appendix II.

In this Appendix information and deductions based on data are given, which need to be considered in connection with the fact that they relate particularly to conditions in Egypt.

Costs.—The Type B installation has been applied on a sufficiently large scale for reliable costs to be available. The new parts required by this system are shown in Figs. 24 to 27. Figures relating to the yearly savings shown by the use of heater engines in Egypt would be of small interest, since that country is unique in many ways, and costs and savings are not on the European basis. However, from figures based on Egyptian State Railways' records, the relative annual expenses shown in Table XI., which would fall on ordinary engines, engines with the Type B installation, and on De Glehn compounds, are given, taking 50,000 as the

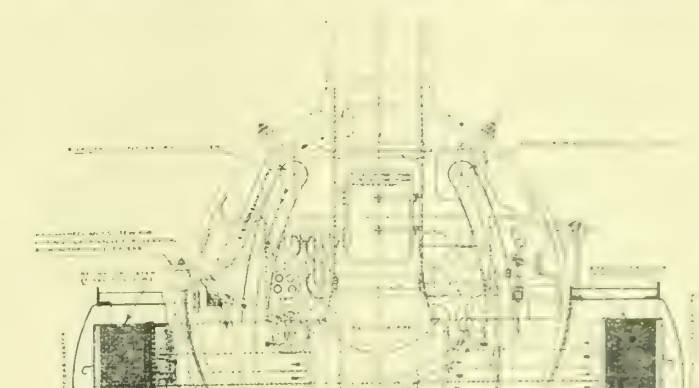
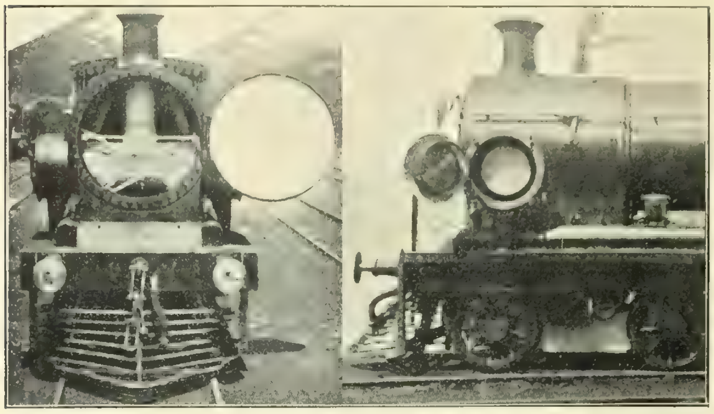


Fig. 36.—High Degree Feed-water Heating and High Degree Superheating System, Type C (Appendix I.). See also Figs. 37 and 38.

yearly mileage and 15s. per ton as the price of coal. The standard 4—4—0 type engines cost £2,568, and run to 1·5d. per mile for repairs. New heater engines of the same class would, according to figures based on tenders, cost £2,718, and their repairs (allowing for no reduction of boiler repairs) would then be slightly under 1·7d. per mile. The De Glehn engines, which are typically French, cost £4,800 each, built by and to the designs of a continental firm, and their repairs amount to 2·7d. per mile. Allowing 5 per cent. for interest, depreciation for a 20-year life, and deductions for the two latter types for coal saving, the approximations shown in Table XI. are arrived at.



FIGS. 37 AND 38.—HIGH DEGREE FEED-WATER HEATING AND HIGH DEGREE SUPERHEATING SYSTEM, TYPE C (Appendix I.).

The reduced coal bills for the heater and De Glehn engines are based on the figures of Table V., which covered lighting up coal, &c., and approximated to service working. In estimating for long periods some discount might be allowed on those figures, but, to them, the inclusive cost of the heaters, whether fitted to existing or to new engines, is small enough to be covered by the savings. On existing engines, it may be pointed out, the actual installing involves no expensive work, the worst matter to be taken in hand being the possible lengthening of the smokebox.

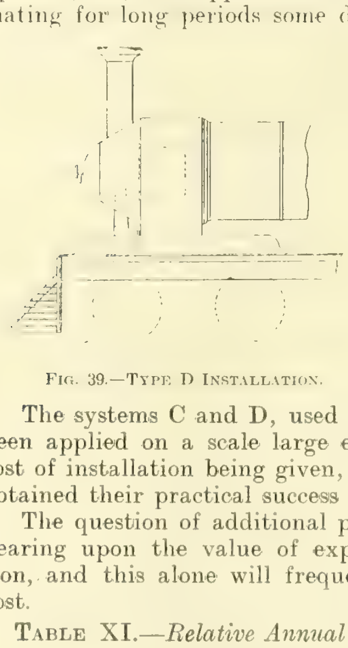


FIG. 39.—TYPE D INSTALLATION.

The systems C and D, used on Engine No. 712, have not been applied on a scale large enough to warrant figures of cost of installation being given, through from the experience obtained their practical success would seem to be assured.

The question of additional power has often an important bearing upon the value of expenditure entailed in conversion, and this alone will frequently warrant the additional cost.

TABLE XI.—*Relative Annual Charges against Ordinary, Heater, and De Glehn Compound Engines.*

	Ordinary engine.	Heater engine.	De Glehn compound.
	£	£	£
Interest	128·4	135·9	240
Depreciation	128·4	135·9	240
Repairs	325	354·1	562·5
	581·8	625·9	1042·5
Coal	754	528	654
Total	£1335·8	£1153·9	£1696·5

Effect of Usage.—The efficiency of the heaters is well maintained in service. In high degree feed-water heating, the deposit found in the smokebox heater has not been great. From the temperatures and pressures reached, it appears that the carbonates or soft deposit-forming salts are thrown down in the exhaust heaters. Most of the more slowly depositing sulphates are probably precipitated before the boiler is reached, but if, as is commonly held to be the case, these deposit chiefly where conditions are favourable to a gradual concentration of the liquid, they are most likely carried through to the boiler, much as usual. Good circulation is encouraged in the smokebox heater. That the boiler is relieved of a large amount of scale-forming matter is clear from the turbid condition of the water coming from the exhaust heaters when blowing through. There is no incrustation in the pump exhaust heater. The artificial softening of water, now frequently adopted, would naturally be beneficial to feed-water heaters. When the smokebox heater is used as a superheater there is no incrustation. Records taken on the Egyptian State Railways, for the Type B system, before and after running over 45,000 miles, showed an apparent drop of 4° Fah. in the superheat, and 2° Fah. in the feed temperature. In the first case, however, the train load was 16 tons heavier than in the second, and it is therefore probable that no real drop occurred.

Life, Deterioration, &c.—The pump deals only with water of about 90°-95° Fah. and may easily be kept in good order. The life of the heaters is partly dependent on the water and the irregularities of pitting. The heater shells stand well, and steel tubes only $\frac{1}{16}$ in. thick are found to last in most cases for about 63,000 miles, a mileage frequently largely exceeded. The life may be increased by using specially-treated tubes, or, by increasing their thickness. The smokebox heaters keep clean inside, and remarkably free from wastage outside, if raised and kept in the warm dry gases. The tubes of these heaters, when used as superheaters, last for as much as 72,000 miles. In a recent case, after 82,000 miles, only a few bad places were found in the whole set of tubes, and no actual failures. The practice has been adopted, however, of renewing all heater tubes when shopping engines for general repairs. This is the heaviest repairs expense, but, comparatively, it is not serious, and might even be reduced by the use of brass or copper tubes.

No conclusive information is available, unfortunately, on the effect of the heater systems on boiler repairs. From the improved condition under which the boiler works, it would be expected that heater engines would show up better than others in this respect. All that can be stated is that, on the Egyptian State Railways, the boilers of such engines are extremely light on repairs.

Iron and Steel Institute.—The annual meeting will be held at the Institution of Mechanical Engineers, Westminster, on May 1st and 2nd, commencing each day at 10-30 a.m. On the Thursday morning the Council will present their report for the year 1912. The Bessemer gold medal for 1913 will then be presented to Mr. A. Greiner. On the Friday morning the Andrew Carnegie gold medal (for 1912) will be presented to J. Newton Friend, Ph.D., and the awards of research scholarships for the current year will be announced. The following is the list of papers that are expected to be submitted: (1) "Critical Ranges of Pure Iron, with Special Reference to the Point A_2," by Dr. H. C. H. Carpenter; (2) "Influence of the Metalloids on the Properties of Cast Iron," by H. I. Coe; (3) "Economy of Dry Blast," by Prof. J. von Ehrenwerth; (4) "Corrodibility of Nickel, Chromium, and Nickel Chromium Steels," by Dr. J. Newton Friend, J. Lloyd Bentley, and W. West; (5) "Influence of Silicon on the Corrosion of Cast Iron," by Dr. J. Newton Friend and C. W. Marshall; (6) "Influence of the Presence of Sulphur upon the Stability of Iron Carbide in the Presence of Silicon," by W. H. Hatfield; (7) "A New Form of Electrically-driven, Two-high, Continuous-running, Reversing Mill," by Andrew Lamberton; (8) "Studies in the Cold Flow of Steel," by Percy Longmuir; (9) "Rolling-mill Practice in the United States, Part II.," by Dr. J. Puppe; (10) "Faults in Present-day Furnaces and their Remedies," by Alleyne Reynolds; (11) "A New Method for Accurate Determination of Phosphorus," by C. H. Ridsdale and N. D. Ridsdale; (12) "Tenacity, Deformation, and Fracture of Soft Steel at High Temperatures," by Dr. Walter Rosenhain and J. C. W. Humfrey; (13) "Chromiferous Iron Ores of Greece," by Herbert K. Scott; (14) "Production of Sound Steel by Lateral Compression of the Ingot whilst its Centre is Liquid," by B. Talbot.

GRIFFIN'S ABSORPTION DYNAMOMETER.

A design of absorption dynamometer, the invention of Mr. Samuel Griffin, Kingston Ironworks, Bath, is shown in the accompanying illustrations, Fig. 1 being a front sectional elevation, Fig. 2 a cross-sectional elevation, and Fig. 3 a sectional plan illustrating the arrangement of cooling water connections. Referring to the illustrations, A is the drum in the interior of which is the rotor B, mounted on the shaft C, to which the transmission coupling is attached. The adjustable metal segments D are fitted with friction blocks, which make contact with the interior of the periphery of the drum A, and are supported by means of the pins F, which slide in the hollow members of the rotor B. Suitable end-long movement is imparted to the pins F by means of the bell crank levers G, which are actuated by the central slotted rod H, to which an end-long movement is imparted from the hand wheel E, levers J, and sleeve K, which slides on rod H. The compensating spring L makes pressure contact between the sleeve K and the collar nuts M, so that the outward or compressing movement of the sleeve K from the hand wheel E is transmitted to the slotted rod H, through the compression of the spring L, contact between the friction blocks and the interior of the periphery of the drum being thus effected through the metal segments D, pins F and bell crank levers G, the ends of which engage in the slotted end of the pin H. It will be obvious that the opposite or inward movement of the rod H will release the contact between the frictional surfaces of the blocks and interior of drum. The central bosses, through which passes the shaft C, are mounted on ball bearings, which are carried on adjustable supports. Cooling water passes through the inlet passages N, being discharged (after passing entirely around the interior of the drum in continual contact with the friction surfaces) through the outlet passages O. One end of the lever P is inserted in either of the sockets shown, according to the direction of rotation of the armature. As shown on Fig. 1, the direction of the rotation is indicated by the arrow. The outer end of the lever P carries a pivoted link, to the lower end of which is attached any suitable static weight, the upper end being connected with any suitable spring balance or other measuring device. In Fig. 3, the direction of rotation of the lower portion of the rotor B, not shown, is indicated by the arrow R the cooling water entering the lower part of the drum by the inlet passages N in the same direction, as indicated by the arrows S. The water, after being swept completely around the interior of the drum, is discharged through the outlet passages O in the direction of the arrows T at a velocity proportional to that of the rotor by which it is actuated. The flexible pipes Q, attached respectively to the inlet and outlet passages, admit of the free oscillation of the drum on its trunnions.

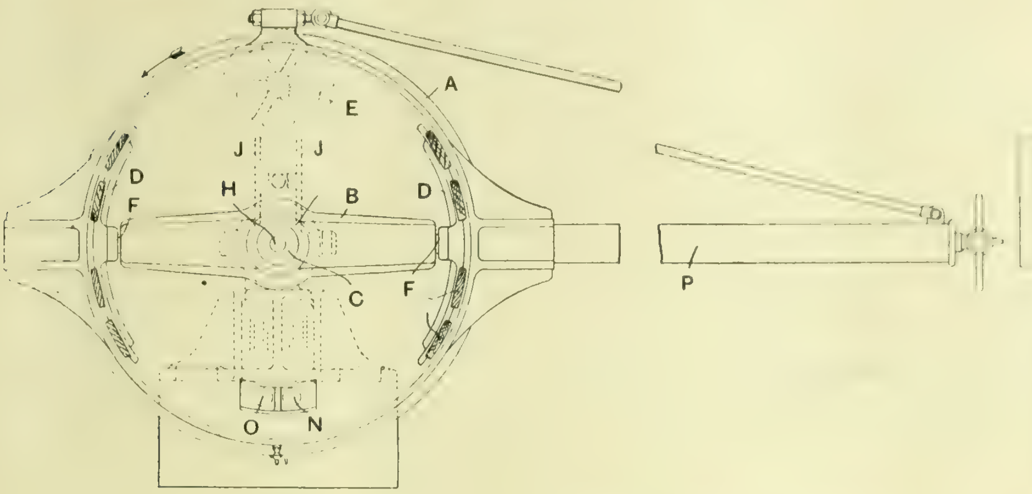


Fig. 1.

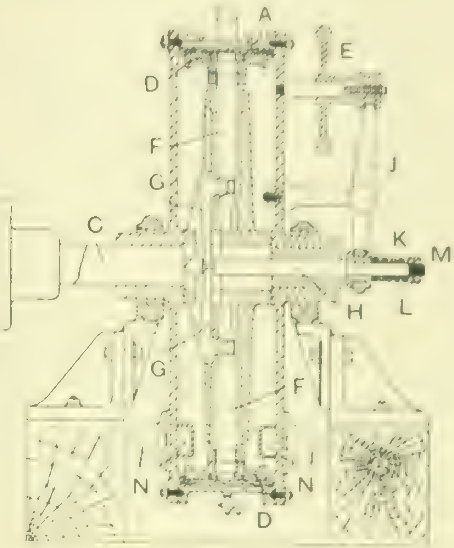


Fig. 2

Griffin's Absorption Dynamometer.

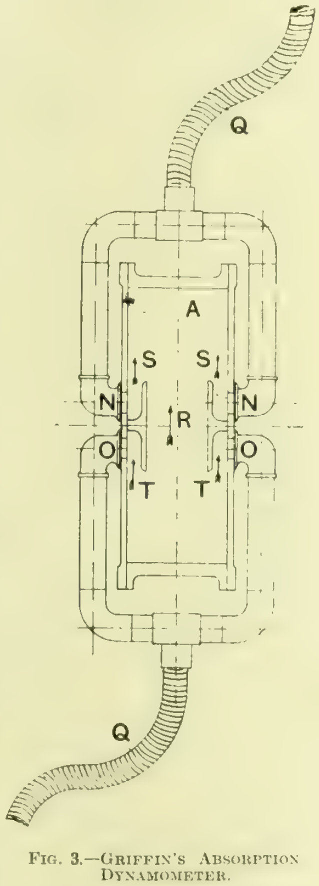


Fig. 3.—Griffin's Absorption Dynamometer.

The action is as follows: The transmission shaft being put into rotation from any source of power to be measured, the necessary amount of cooling water is passed through the drum. The friction blocks are then brought into forcible contact with the interior of the drum by means of the mechanism described, actuated manually, the force exerted on the friction blocks being proportional to the load to be lifted at the outer end of the lever. The compensating spring, through which the necessary movement to operate the friction blocks is transmitted, serves to maintain a uniform pressure on the friction blocks, the friction between which and the interior of the drum thus remaining sensibly constant for any given load. The effect of the above-described operations will be to slightly rotate the drum on its trunnions, thus lifting the load at the outer end of the lever, the power or energy transmitted thereto being measured or computed in the usual way.

Canals and Canalised Rivers.—At a recent meeting of the Association of Birmingham Students of the Institution of Civil Engineers, Mr. J. A. Sauer delivered the first of the two Vernon-Harcourt lectures on "Canals and Canalised Rivers." The lecturer said he proposed, before entering on the technical side of the subject, to give some historical account of the canals and canalised rivers, and proceeded to trace the development of canals from the earliest times. Giving the history of English canals, he said there were 4,763 miles of canals in this country at the present time. He complained, however, that owing to the number of different owners and the fact that they had been developed as individual enterprises, there was no uniformity of the English canals, and it was practically impossible to make a national use of them. There were, for example, no fewer than seven different ownerships between London and Cheshire. Many of the canals had fallen into the hands of the railway companies, who, rightly or wrongly had preferred not to reconstruct them. He referred to the Royal Commission, and explained the recommendations they made. The Government, he said, had not yet seen their way to adopt these suggestions, and in consequence this useful system of transport remained in its present chaotic condition.

RECENT DEVELOPMENTS IN THE MANUFACTURE OF TINPLATES.*

BY H. SPENCE THOMAS.

THE manufacture of a tinplate from the time the steel bar is received at the works until the finished tinplate is complete, packed ready for shipment, practically occupies a week. The plate goes through seven departments, and the approximate time in each is as follows: (1) Mills 24 hours, (2) black pickling ½ hour, (3) black annealing and cooling 74 hours, (4) cold rolls ½ hour, (5) white annealing and cooling 58 hours, (6) white pickling ½ hour, (7) tinning, assorting, and packing ½ hour—or a total of 158 hours.

In the engineering side of the tinplate works there has been great development in order to deal with the stronger and heavier machinery, which calls for repairs from time to time. For example, the rolls of the tinhouse are now over 7ft. long as against 3ft. 25 years ago, thus calling for very much stouter and more exact lathes. In some works grinding machines have been employed for truing up the tinhouse rolls, but there is not any consensus of opinion as to their suitability for this purpose, as a good man with a file can generally produce satisfactory results.

Twenty-five years ago the common size of the mill rolls was 26in. long by 18½in. diam., with 13½in. diam. necks, but to-day 28in. by 21in. diam. with 16in. diam. necks is quite common, whilst at least one works are running some of their tin-mill rolls 28in. long by 24in. diam., with 18in. diam. necks. The steel bars were 6½in. wide and a "piece"

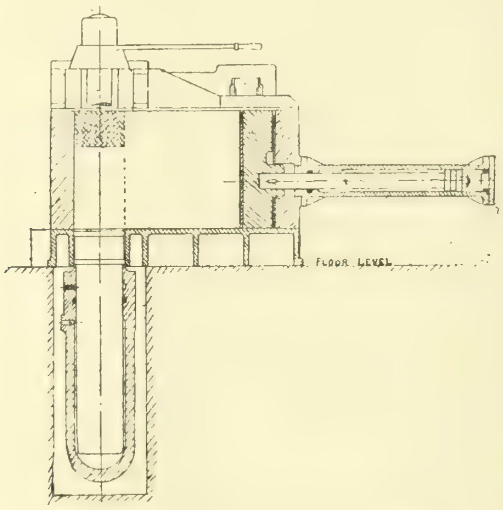


FIG. 1. -200 TON HYDRAULIC SCRAP PRESS.

weighed 27lbs., 25 years ago; whilst to-day, the bars are generally 9in. wide and the "piece" often weighs 35lbs. Practically no lighter substance than Common was produced (except Taggers) before the McKinley tariff; but to-day "light" plates are the vogue, and the workmen are paid on the same scale for them as if the heavier weight was handled.

Whilst there has been no alteration in the shape of the mill furnaces, there is a great diversion of practice between different works as to the material of which the hearths of the furnaces are made. Some works go in for brick bottoms, plain or corrugated, others for cast iron, whilst many prefer to have the hearth made of ordinary coals. Producer-gas-fired furnaces have been tried, but the advantages have not always been sufficient to justify their retention. Gas furnaces on the regenerative plan also have been put into use, and are now working. Gas-fired furnaces, however, have not found general favour in English practice. "V" sections of bed and standard possess many advantages, and are sometimes used, but time will decide as to their retention.

Streams of cold air or water on the necks of the hot rolls are used at some English works. Americans lay it on at a stated time every week. In America, at the Newcastle plant, there are 30 mills in a line, one engine to each lot of 10 mills of one pair of rolls, all rope-driven. The biggest unit in England is six mills of two pairs of rolls per mill. American practice gives 1,500 to 2,000 boxes per mill per week, whilst the English average is half of this quantity. In English mills only about 25 per cent of the effective rolling capacity of the mill is utilised, and where a sufficiency of engine power and suitable plant exists, the output in England can very well be doubled by double-manning the mills, as in America, and still leave a margin of 50 per cent.

The improvements in hammers and lathes permitted the introduction of direct-acting engines with mills on both sides of the crank, with large flywheels (sometimes on both sides), and some fine examples are to be seen in the tinplate works. On the other hand, various troubles have eventually arisen with many of these big shafts, which doubtless influenced the decision of many firms to put down the fine rope-driven plants, largely on American lines, now so common in the trade. Several of the later plants have adopted the Uni-flow type of engine. This is quite a departure from the ordinary compound engine, and many doubts were expressed as to the practical and economic results; but apparently the users are satisfied, as they have given repeat orders. Simplicity and low first cost are the strong features. Electricity has been utilised as a motive power to drive tinplate mills, and to the Redbrook Tinplate Company, Ltd., is due the credit of being the first to adventure and succeed in this connection. Lately at Swansea there has been laid down a fine electric installation having 12 mills driven by three motors. The whole of the current for the works is generated by steam on the spot, and it is said to be a part of a huge scheme of blast-furnaces and steelworks. At only one works has a gas engine been adopted to drive tinplate mills, and this is an engine of 350 h.p. running at 170 revs. per minute, driving by means of ropes on to a flywheel running at about 40 revs. per minute. Twenty-five years ago a 40-ton flywheel 20ft. diam. was the biggest known in the tinplate trade, and drove four mills as a unit, whilst to-day there are some weighing 150 tons by 36ft. diam., on the mill shaft driving six mills.

The vast improvements in the machinery and plant at the modern tinplate works give great advantages to the employés, permitting more work to be turned out with less effort, mental and physical, than in older works where an insufficiency of engine power may exist. This improved turn-out must be obtained to equalise the huge capital expenditure charges for interest and depreciation, which amount to about 6d. per box, as against less than 1½d. at others.

The "Crocodile" type of shears is universal in the English tinplate trade. Most of these, both for the doubling as well as the mill shears, are generally driven from the mill shaft by means of cranks or rockers, the latter drive being the favourite. At some works, however, the shears are driven by means of a line shaft down the mills, driven off the main engine shaft, or actuated by an independent motor, steam or electric. This latter gives a very neat arrangement, and allows the line shaft to be idle, as well as the doubling shears when the latter are not required for the mill work. American practice calls for an electric motor for each of the doubling shears, so that this shear is never operated except when it is actually required, which saves wear and tear. With regard to the mill shears, in American practice the guillotine squaring shears are almost universally used.

Scrap bundling is mostly done, as from time immemorial, by tying up in bundles, but some eight years ago, Major Lewis first introduced a most successful hydraulic scrap press, principally to deal with the scrap from his Gorseinon Works backplate circling machines; it is utilised to deal with the mill scraps as well now. Messrs. Broadbent & Sons, of Huddersfield, have lately delivered a somewhat similar press (see Fig. 1) to Melingriffith Works, where it has just been erected. This press consists essentially of a large strong box provided with a movable lid. Into the box are placed the scraps, rough as they come from the shears, and when the lid is closed the horizontal ram is made to travel up to a fixed point, where its face forms the fourth side of the box, and is locked there. The vertical ram then begins to move upwards, and so compresses the already partially-compressed bundle, whilst, in order to give the block of scraps a greater degree of solidity, an intensifier is brought into action on the vertical ram and the block (cross-etched in sketch) pressed still closer. The pressure is then relieved, the lid opened,

* Abstract of paper read before the South Wales Institute of Engineers, March 18th, 1913.

and the block removed; the hydraulic pressure used is 1,500lbs. to the square inch, and that obtained from the intensifier is 4,000lbs. per square inch. The hydraulic pressure is generated by a motor belt-driven hydraulic pump through the accumulator.

There has been no great alteration in the last 25 years in black pickling, except towards greater outputs per machine owing to the various improvements in the plants, while the consumption of vitriol per box is, if anything, greater. Chemists say that the average consumption of sulphuric acid per box is more than double what is necessary. Instead of building up the "Greys" type of pickling machine of wood and cast iron, sometimes attaching it even to the roof, a much improved plant has been introduced of building the machine up wholly of structural ironwork independent of the roof, and particularly in adding to the machine a novel pull-over device which rapidly changes the cradle from one vat to another, thus doing away with a goodly portion of the hard and laborious hand labour. The spent liquor from the black pickling is conducted to the copperas plant and there crystallised out, and sold as "green" copperas in crystal form. There are three methods of dealing with the spent liquor: (1) Cool and crystallise out in tubs, then concentrate and repeat; (2) concentrate by boiling by means of steam coils, and then cool and crystallise; (3) concentrate in bulk and again in pans. Nos. 1 and 2 produce the green copperas of commerce, whilst No. 3 process produces cake or slab copperas.

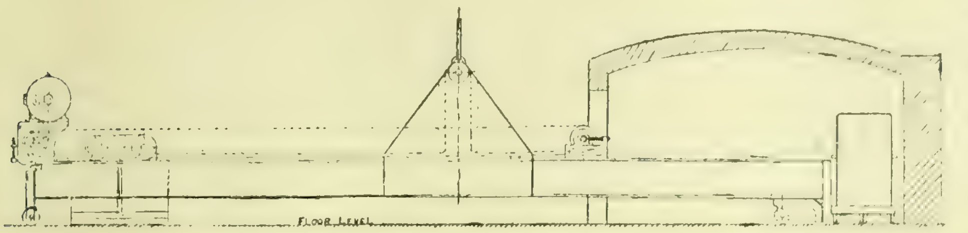


FIG. 2.—ELECTRIC CHARGING MACHINE.

In America all the pots are handled by overhead cranes with hooks for the annealing pits, whilst with floor or horizontal furnaces a charger, termed a "goose-neck," is generally used. By these mechanical means America is a great way ahead of the generality of our English works, which usually employ the old long-handled two-wheeled coach, and by the main force of eight men move the pots and charge the furnaces under most trying physical conditions. All the modern works built since 1907 have overhead cranes commanding their annealing furnaces and floors, thus minimising the labour, and some of the furnaces have movable hearths. Most of these modern furnaces are coal-fired, producer gas presenting some difficulties. At one works there is said to be a continuous annealing furnace, where the pots are pushed in one after the other on a ball race down a long culvert or furnace. About midway down this culvert there is, on the side, a firegrate, and the gases of combustion pass over and along the pots towards the entrance end, and are drawn off, regulated by dampers, to a chimney. A similar device is being successfully used at works for galvanised sheets, and there is much to be said for the principle.

At the Melingriffith Works, owing to the restricted area and the increased mills, it was found necessary to consider the remodelling of the annealing room, when the following scheme was adopted: (1) To retain the existing roof principals span, but to obtain new columns and lift the roof 12ft., making a headroom of 27ft. by 252ft. long. (2) To put in an electric overhead crane. (3) To erect three new annealing furnaces 2ft. higher than the old ones under the lean-to roof. (4) To construct a charging device capable of commanding these annealing furnaces outside the main bay, but to be attached to the crane in the main bay. (5) To have annealing pots the same breadth and length as before, but 44in. high instead of 24in. This change has been effected with beneficial results to all concerned.

The charging device suitable to the foregoing set of circumstances at Melingriffith Works is shown in Fig. 2. The charger consists of a long beam suspended from the overhead crane hook at about its middle, having a movable counterpoise of about 5 tons, capable of being moved backwards and forwards along the beam. The counterpoise is actuated by means of an electric motor with clutch gear and an endless chain, and is locked by a brake in such a position as to maintain the beam in equilibrium whatever weight, within its capacity, is placed at the charging end of the beam. This arrangement allows the "charger" to enter the furnaces, which are situated under the lean-to and outside the main annealing roof, and thus adds considerably to the area of ground commanded by the crane. This tool has been working quite successfully for more than 12 months, and only requires one man on the floor. It was found desirable to make the legs of the annealing stands 7in. high instead of 3in., so as to readily allow the prongs to get under the same whilst the plates were better annealed. Again, in dealing with the annealed plates a false stand was invented, which helps the annealing process and at the same time is a great aid in transporting the plates from place to place, apart from the regular stands and free from the dusty sand. In order to give the men in the annealing department a better command over the work, and avoid the heavy labour of sledging, a compressed-air plant by the Ingersoll Rand Company, with six pneumatic hammers, was installed.

In America the rolls for cold rolling are invariably arranged tandem fashion, with conveyers between, thus eliminating about 60 per cent. of the labour usual in English works. In the last 25 years there has been practically no alteration in the practice here, except that the engines and machinery generally are stronger, and possibly a heavier pressure is carried on the rolls. Rope-driven plants are common to-day, and give excellent results and smooth running.

The remarks on black pickling largely apply to white pickling. In addition, many works have installed overhead single mono-runways, which in some cases are used in order to transport the cradles from the white pickling machine down into the tinhouse alongside the tinman's trough, where the plates are ranked straight from the cradle, and so any handling of the plates in the white pickling department is avoided. This arrangement is only possible in the recently erected works. Some of the older works use this same monorail system to take the plates from the white pickling department into the tinhouse, thus easing the work very considerably. This method is particularly welcome because it minimises labour.

In the last 25 years great changes have taken place in the tinhouse, but all practically within the first five years of the period under review. Firstly, flux (zinc chloride, usually made by "killing" muriatic or hydrochloric acid by the

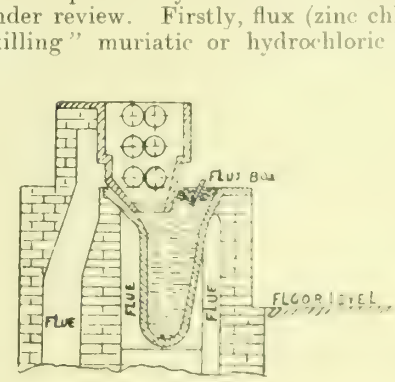


FIG. 3.—"PLAYER" POT.

addition of zinc, first introduced about 18[illegible]) was more carefully and successfully prepared in the latter eighties, and replaced the palm oil, then almost universally used, for fluxing the prepared steel plate preparatory to dipping it in the molten tin, or terne, mixture. Secondly, this perfection in the manufacture and use of flux permitted the more ready adoption of machinery to coat the plates, and with the terrible blow of the McKinley tariff in 1891 the brain of the industry concentrated itself upon improving the tinning machines, which appeared in the following approximate chronological order: Duffryn machine, Taylor-Struve machine,

Thomas & White machine, Player machine, Lydney machine, and Melingriffith machine. Most of these are working to-day, but so improved that their capacity has been doubled, and in some cases nearly trebled, while the wage rate per box remains the same. The tinning machines to-day can be roughly divided into two types, viz.: (1) The "vertical," of which "Player's" is the best example (see Fig. 3), and (2) the "half-round," an example of which is the Melingriffith pot (see Fig. 4). All are well known in the trade, and need no description here, except to say that the "Player's" machine, certainly the most original and ingenious, contains within itself a catching device; hence all the other machines have been handicapped to that extent, but the last seven years have seen many schemes advanced to overcome this drawback.

Of these devices, perhaps the James is the favourite. In the James machine the leading edge of the plate, as it emerges from the top pair of grease-pot rolls in a vertical direction, is guided towards, and threads itself through, three roller guides which lead the plate over towards the conveyer, but at the same time maintain the rearmost end of the plate in such a position as to minimise the "list" or thick line of tin along the lower edge of the plate, as it leaves the top pair of grease-pot rolls. The plate is then guided, as mentioned before, towards the conveyer on to which it falls, and the conveyer, travelling in a horizontal direction, deposits the plate into the branning machine, without being touched

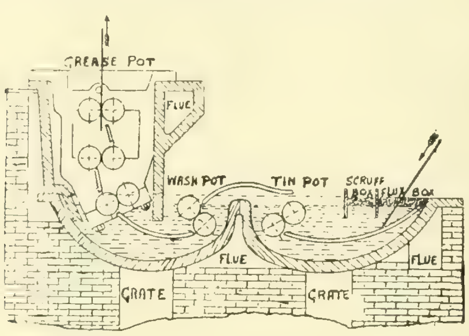


Fig. 4.—"Melingriffith" Pot.

or handled at all. A device is placed in connection with the branning machine so as to only permit the plate to enter the machine when the latter is ready to receive it. Several of these machines are working at various works, and it is claimed by the inventors that considerably less tin is wasted upon the "list" edge of the plate than is the case when the plates are dealt with by hand, or even by any other mechanical device.

America is equipped from end to end with catching devices of various kinds, working satisfactorily in conjunction with the "half-round" tinning machines (mostly of the "Thomas and White" type). Combined branning, of the "half-round" type, and dusting machines are employed in the majority of works, although some plates of a special character are still cleaned by hand. The present method of coal-firing under the tinning machines is most crude, and it would appear as if better heat control must be obtained to give the best results. On the Continent, in many of the modern works, pyrometers are regularly fixed on the tinning machines and other points to indicate the working temperatures.

To-day the consumption of tin per box of tinplates, whilst kept a profound secret, probably varies but little as between one works and another, whereas 25 years ago the differences were great. In any event, it is known that a quarter of a century ago some works were consuming almost as low as 2lbs. of tin per standard box of tinplates, but it is with a degree of regret that one is forced to admit that to-day, after 25 years of endeavour, there is but very little, or at all events insufficient, improvement in this respect.

It has been the dream of many to coat the iron or steel sheet with tin by means of electricity, and so eliminate the very costly labour at present employed in this department, and at the same time reduce the consumption of the expensive metal, tin, and still obtain a well and properly-coated sheet. But apparently there is something in the nature of tin, in its relation (electric or magnetic) to iron and steel, which prevents the formation of an alloy and the proper union of the two metals, so far as experiments up to date have gone. Steel plates have been coated with tin by means of electricity, but only in an experimental stage.

A beginning has been made in the Swansea district to coat backplates with aluminium (it is said by a cold wet electric process), but it is early yet to state whether they will grow into general use, as it depends on their cost as compared with tinplates, and what their comparative utilities are as against the better-known article. In any case it must be admitted that in all probability the recent high cost of the tinplate has favoured the introduction and extended use of competing substitutes for packing conserves.

Assorting-rooms are still constructed much on the old lines, although some works have made departures from the old practice in the arrangement of their tinhouse and assorting-room, having in view a saving in the handling of the finished plate.

There is but very little difference between the sizes of the castings and other such machinery used at the different tinplate works; for instance, the wobblers in Welsh works have always four flutes, but it is seldom that these are interchangeable except at their own works, because even where the greater and lesser dimensions across the wobblers are the same, the shape is different, thus preventing the interchange of castings. If only a standard for this and other such matters could be agreed upon by the trade, a very large economy would be effected. Possibly a committee formed on the same lines as the Engineering Standards Committee could take these matters in hand, and probably the Tinplate Makers' Association may feel inclined to take up the subject.

There is so much of an apparently mysterious nature that is unknown in regard to the tinplate trade, and the factors governing the consumption of tin, that one would like to see some of the younger generation, who have had the benefit of a scientific training, devote their time and energy in the direction of systematically investigating these matters with a free use of both microscope and pyrometer. The following points occur to nearly every tinplate works' manager as worthy of research: (1) The result of hot and cold rolling in the mills; (2) the result of a high peripheral roll speed in the mills; (3) the boshing and non-boshing of the iron in the mills; (4) over and under black pickling, and influence of strength and temperature of the acid solution, also of time; (5) effect of varying temperatures and time of annealing; (6) light and heavy cold rolling; (7) temperature effects in the tinning operations; (8) differences from the tinplate trade point of view between acid-Bessemer steel, basic Bessemer steel, acid open-hearth steel, basic open-hearth steel, and the comparative tin consumption for each kind.

The raw material supplied by the steel-makers in the shape of steel bars shows great improvement in quality, and particularly in its regularity, permitting deeper stamping to be made and creating greater confidence in the minds of those who work up the tinplates into various shapes. To several has occurred the idea of the establishment of an office which would probably incorporate some of the present tinplate samples into a kind of Lloyd's Proving House, whose certificate as regards the quality, condition, sheetage, and weight of the tinplates should be accepted by all concerned; a clause embodying this as a condition to be inserted in all tinplate contract notes. This would be welcomed by most buyers and sellers, and would avoid many causes of friction in the merchanting of the cheapest finished article in the world.

There is at the present time considerable development in the tinplate trade abroad, particularly on the Continent; existing works are extending, while a number of important schemes are projected. Needless to say, these works are to provide primarily for their own home consumption, now mostly supplied by England. When it is remembered that only 20,000 boxes of tinplates were produced in the United States of America in the year 1891, whilst to-day such a vast industry has been created within the short period of 22 years as to easily exceed the English trade, which has been in existence nearly two centuries, one is struck with the possibilities of the position.

TESTS TO DETERMINE THE RELATIVE VALUES OF HIGH SPEED AND CARBON TOOL STEELS.

IN the transactions of the American Society of Naval Architects and Marine Engineers, Mr. L. H. Kenney gives the following particulars of the tests adopted by the United States Navy to determine the relative values of high speed and carbon tool steels.

Previous to 1909 each navy yard prepared requisitions for the purchase of tool steels for its own purposes. The requisitions specified either proprietary material or that the contract would be awarded from the information obtained by a test of samples submitted. By this method there was no uniformity in the specifications. In order to centralise the purchase and standardise the tool steels, a tool steel board, in 1909, recommended that the Philadelphia navy yard be the purchasing station, and prepared specifications for one high-speed and three carbon steels.

The chemical composition of the high-speed tool steel specified differed from any of the commercial steels, and the carbon tool steels were varied principally in the carbon content, in order to adapt them to the purposes for which such steels are generally used. The contracts were awarded under these specifications to the lowest responsible bidders. As part of the inspection for acceptance of the material, physical tests were prescribed in addition to the chemical analyses, but the physical tests never gave satisfactory or decisive results, and evidently were not co-ordinate with the chemical compositions. The specifications did not provide a means for either ascertaining the relative merits of the tool steels offered by the bidders or if there were better tool steels than those within the limits of the chemical compositions specified.

It was therefore considered advisable to revise the specifications so that the bidders would be required to submit samples. The samples would be manufactured into tools and subjected to physical tests devised to investigate the relative merits. The data thus obtained would form the basis for recommending the award of contract. The chemical compositions would be given with maximum and minimum limits, in order to indicate to the bidder the kind of tool steel required, but as the physical test would form the basis for recommending the award of contract, a statement would be included to the effect that the bidders could submit samples of chemical compositions differing from those specified. The object of this provision was to introduce competition as to the qualities of the tool steels instead of simply competition in price. By modifying the specifications as outlined, means would be provided for learning something of the relative merits of the commercial tool steels, and for taking advantage of developments and progress made by the manufacturers. Definite information would also be obtained of the qualities of the steels before the contract was awarded.

Specifications were prepared for the purchase of high-speed tool steel for the United States Naval Academy. The limits of the chemical composition were varied to permit bidders to submit proposals on their commercial standard tool steels, and the feature of a selective test was introduced. The selective test provided means for investigating the relative suitability of the tool steels offered, and the recommendation for award of contract was based on the information thus obtained. The specifications required each bidder to furnish a sample bar of the tool steel covered by his bid, and this sample bar would be delivered to the engineer officer for him to direct the selective test. The proportion of the tool, its heat treatment, and the conditions of the test are covered by the selective test. A lathe tool was selected for the test and it was kept cutting, without lubricant, until it failed by the cutting down of the cutting edge due to heating caused by the friction of the chip, and a record of the elapsed time of run, or cutting life of the tool, was made. By keeping the other conditions constant the elapsed time of run was the principal variable. Each tool after failure was reground, care being taken to remove the effects of the heating due to the previous cut, and again tested until the tool broke down, after which it was reground and tested a third time.

It was considered that the cutting life, as shown by the elapsed time of run prescribed and cost of the material, were the principal factors in determining a selection, because the number of times the tools could be reforged and reground, and the cost for keeping them in efficient condition, would be practically the same regardless of the quality of the tool steel. Therefore the arithmetical mean of the elapsed time of all runs of the tools of one sample was computed and this mean was divided by the price per pound of the material. The quantity thus obtained was called the selective factor, and the tool steel of highest selective factor was recommended for award of contract.

An estimate was made to determine the relative values of the several tool steels tested by computing first the value for each sample which would give it a selective factor equal to the highest factor, and, second, to determine the value of the tool steel of highest selective factor to obtain a selective factor equal to that of each sample. A test was made of tool steel which had been purchased under specifications, to learn if it were equal or superior to the commercial tool steels, and it proved conclusively that some of the commercial tool steels were superior.

The selective test was conducted under uniform conditions, so that the principal variable was the elapsed time of run of the tools. Electrical observations were made of the input to the motor which drove the lathe. They showed that the work done by the tools varied. It was decided to compute the work value or watt-minutes of work done by each tool first, and then adjust the work values by the principles of least squares instead of elapsed time of runs, as was done in the previous test. By the previous method an observation of the elapsed time of run of a tool might vary so greatly from the mean that it would be rejected, although the watt-minutes of work done by a tool might not vary sufficiently from the mean work value to necessitate rejection. The work done by a tool, which is indicated by the elapsed time of run and the watts consumed, is an important factor in determining selection. It was decided therefore that the work value of each tool was a fairer value.

The information obtained from the selective test conducted on high-speed tool steel indicated that it was advisable to revise the specifications for carbon tool steels, and a selective test similar in character and purpose to that previously described was introduced. Four classes of carbon tool steel were selected which varied principally in their carbon content. The conditions throughout the selective test were maintained as nearly constant for each class of tool steel as facilities would permit, and the elapsed time of run, or operating life of the tools, was the principal variable in the test, because the tools were operated until they broke down.

The milling cutters for the selective test of carbon tool steel were operated until they broke down either in the shank or teeth. The elapsed time of run of the cutters was recorded and represents the total time the cutters were operating, but does not include the time required to return the milling machine table to the starting point and to set for the next cut. The selective factor represents the ratio of the mean elapsed time of all cutters of one sample and the price per pound of that sample. The relative values were computed as previously described for tungsten tool steel.

The conditions throughout the selective test were maintained as nearly uniform as facilities would permit, and the operating life of the tools determined as previously described. Before the tools were treated a determination was made of the decalescent point of each sample to assist in selecting suitable treating temperatures. Some of the bidders took advantage of the clause in the specifications which permitted tool steels to be submitted of a chemical composition differing from that specified. Tool steels containing tungsten were submitted under carbon tool steels, and a tool steel containing chromium was submitted under carbon tool steel.

The five tungsten steel tools made from the sample bars are stamped with the schedule number, or index number assigned to each sample, and consecutive numbers for the tools of one sample. All tools are hand forged to the No. 30 lathe tool fork of the Sellers system of tool forms. The following day the tools are treated, two furnaces being required for this purpose. In one furnace a temperature of 1,600° to 1,700° Fah. and in the other a temperature of 2,100 Fah. are maintained. The tools are uniformly heated in the low-heat furnace and then in the high-heat furnace.

The temperatures given do not indicate the temperature at the nose of the tool, because the temperature where the thermo-couple is will be higher than at the nose of the tool, depending somewhat upon the size of the opening through which the tool is introduced into the furnace. In order to reduce the radiation loss to a minimum and obtain a satisfactory temperature for the nose of the tool, it has been found advisable to close with bricks the opening into the furnace so that it is just large enough to admit the tool. After the tools are removed from the high-heat furnace they may be cooled either by directing a heavy blast of compressed air on the nose or dipping the nose into oil. The oil should be cooled and agitated by some means such as compressed air. The oil was used for these tests, and is considered preferable because it is less noisy and expensive than compressed air. Tests which have been made indicate that better results are obtained by oil cooling. The tools are cooled in the oil until they are black hot, when they are removed and placed on a cooling table.

After the heat treatment the tools are ground to the No. 30 Sellers system of lathe tool forms and later tested on a nickel steel forging. All tools of a selective test are tested on one forging, because it has been impossible to obtain nickel steel forgings of identical characteristics chemically and physically. The depth of cut, feed and cutting speed are constant throughout a selective test, so that the quantity to be determined is the elapsed time of run, or cutting life of the tools. All tools are tested to destruction, after which they are reground and retested until each tool has been tested three times. No lubricant was used on the tool during the test. The action of the tools when cutting is very interesting, indicating that the material is torn from the forging instead of being cut. The chip wears at first a depression in the face of the tool back of the cutting edge, and the heat generated by the friction of the chip softens the tool. The generation of heat and wearing away of the tool continue until the depression, increasing in size, finally reaches the cutting edge, which suddenly breaks down. It is necessary to grind off about $\frac{3}{32}$in. from the top and end of the tools to remove the effects of the heating. A voltmeter and ammeter were installed, and later a graphic wattmeter to determine the input to the motor of the lathe. By this means the average watts of the friction and cutting loads, which were found to be nearly constant, were determined, the difference between the net watts which, multiplied by the elapsed time of run of the tool in minutes, gave the work done by the nose of the tool measured by the resistance the forging offers to it. The elapsed time of run for a tool depends somewhat upon the dissipation of heat generated by the friction of the chip, and it has been noted that the steel forging on which the tools are cutting will heat up considerably if it is of small diameter and operated at a high cutting speed. The elapsed time of run decreases as the temperature of the forging which the tool is cutting increases.

Each sample of carbon steel submitted for selective test was tested to determine the decalescent point. All tools were heated to a temperature slightly above the decalescent point and quenched in brine, after which the temper was drawn in a lead bath. The cutting tools were then ground and were ready for the selective test. The proportions of the milling cutter used for the test for carbon tool steel were adapted from an article by A. L. Deleeuw, described in the "Transactions" of the American Society of Mechanical Engineers. The principal difference from milling cutters in general use is in the comparatively small number of teeth permitting a larger clearance for the chips. This cutter is so small that it was necessary to support the outer end to enable it to stand the heavy cut desired to give a breakdown test similar in purpose to that developed for tungsten tool steel. The cutter was operated at the speed of 370 revs. per minute, feed 20in. per minute, and 0·08in. depth of cut through the full table travel of the milling machine. The table was run back to the starting point and reset as often as necessary until the cutter failed. The cutter was run without lubricant in order to make the test as severe as possible. There was a generation of heat similar to that developed by the tungsten tool steel test which would draw the temper of the cutter, causing the cutting edge to break down. Sometimes the dulling of the cutting edge would increase the torsional stress until finally the physical strength of the cutter would be exceeded and cause it to break in the shank. Tungsten apparently gives to tool steel the property of resisting heat breakdown.

TABLE I.

Tungsten tool steel.	Per cent. limit.	
	Maximum.	Minimum.
Carbon	0·75	0·55
Chromium	5·00	2·50
Manganese	0·30	0·05
Phosphorous	0·015	0·00
Silicon	0·30	0·00
Sulphur	0·02	0·00
Tungsten	20·00	16·00
Vanadium	1·50	0·35
Iron	*	*

* Remainder.

The observations of the carbon tool steels do not agree as closely as those for tungsten tool steel, and the causes for the variations are not very easily determined. In the case of the milling cutters the cutting life is considerably reduced if there is very much vibration, and in order to overcome this as much as possible a heavy, rigidly constructed milling machine was used. If the cutters were not exactly central in the arbor so that they did not rotate around their geometrical axis, vibrations would be set up which would increase in violence until the cutter finally broke down, and it was therefore necessary to very carefully fit the cutters into the arbor.

The pneumatic chisels were operated by a man, which, of course, introduced a greater variation than if a machine were used. The condition of the chisel at the end of the test, as to whether or not it should be stopped, is sometimes a question of individual opinion, such as the degree of dullness, the amount of reduction in width of cutting edge due to wearing down, &c.

The treating temperature for the tungsten tool steel can be varied through a short range in the vicinity of 2,250° Fah., without producing much variation in the results of the physical test. The treating temperature of the carbon tool steels seems to be within narrower limits, which may perhaps account for some of the variations in the test. It is, of course, extremely difficult to hold the furnaces, which are of the oil-burning type, to absolutely definite temperatures.

TABLE II.

Carbon tool steel.	Class 1, per cent. limit		Class 2, per cent. limit		Class 3, per cent. limit		Class 4, per cent. limit	
	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.
Carbon	1·25	1·15	1·15	1·05	0·95	0·85	0·85	0·75
Chromium	†	†	†	†	†	†	†	†
Manganese	0·35	0·15	0·35	0·15	0·35	0·15	0·35	0·15
Phosphorous	0·015	0·00	0·015	0·00	0·02	0·00	0·02	0·00
Silicon	0·40	0·10	0·40	0·10	0·40	0·10	0·40	0·10
Sulphur	0·02	0·00	0·02	0·00	0·02	0·00	0·025	0·00
Vanadium	†	†	†	†	†	†	†	†
Iron	*	*	*	*	*	*	*	*

*Remainder. †Optional.

The test of the carbon tool steel which contained tungsten showed less vibration than the carbon tool steels without tungsten. This may indicate that the addition of tungsten increases the treating temperature limits slightly without affecting the results of the physical test very much. The addition of tungsten seems to produce two desirable results: The increasing of the cutting life of the tools and increasing the treating temperature limits of the tool steels. The tool steel containing this element apparently does not require any different method of treating from that in general use for carbon tool steels.

Tungsten Tool Steel.—Lathe and planer tools, milling machine tools, and, in general, all tools for which high-speed steel is used. The chemical specifications for tungsten tool steel are given in Table I.

Carbon Tool Steel Class 1.—Lathe and planer tools and tools requiring a keen cutting edge combined with great hardness, for finishing shrinkage dimensions on nickel steel gun forgings, drills, taps, reamers, and screw-cutting dies.

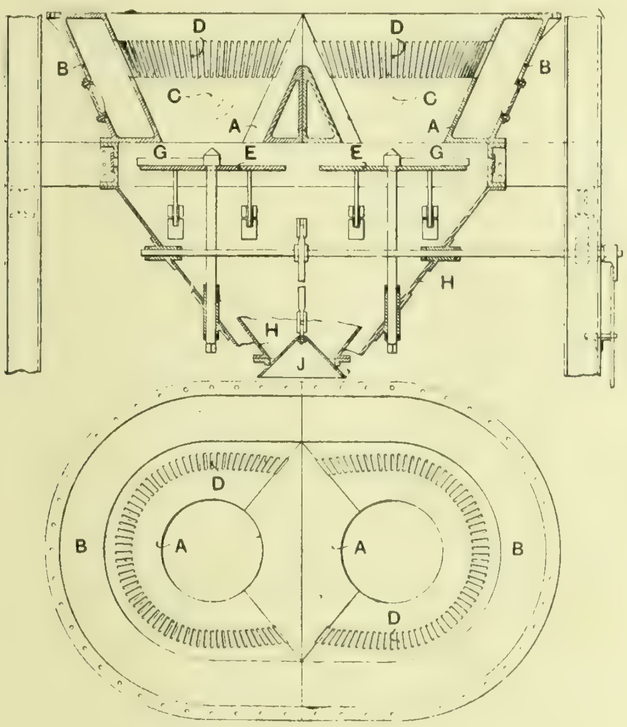
Carbon Tool Steel Class 2.—Milling cutters, mandrels, trimmer dies, threading dies, and general machine shop tools requiring a keen cutting edge combined with hardness.

Carbon Tool Steel Class 3.—Pneumatic chisels, punches, shear blades, &c., and in general tools requiring a hard surface with considerable tenacity.

Carbon Tool Steel Class 4.—Rivet sets, hammers, cupping tools, smith tools, hot drop forge dies, &c., and, in general, tools which require great toughness combined with the necessary hardness. The chemical specifications for carbon tool steel are contained in Table II.

IMPROVEMENTS IN DRY-BOTTOM GAS PRODUCERS.

In dry-bottom producers of the kind which in sectional plan are considerably greater in length than in width, the even removal and discharge of the ash from the bottom thereof and the even distribution of the blast are matters of some difficulty, and with a view to overcoming these the Dowson and Mason Gas Plant Company, Ltd., Alma Works, Levenshulme, Manchester, in conjunction with Mr. Q. Moore, have designed and patented the arrangement illustrated herewith. The producer is in plan of length substantially greater than its width, and with rounded ends, and as shown there are provided at its bottom two inverted truncated conical grates A. These grates are each surrounded by an inverted truncated casing B,



IMPROVEMENTS IN DRY-BOTTOM GAS PRODUCERS.

made in a piece with the grate, the grates and casings conforming to the rounded ends of the producer at their remote parts, whilst at their adjacent parts the casings are flat and vertical, so that they abut each other, and the grates merge in one another. The grates and casings as a whole are the same projected area in plan as the plan area of the bottom of the producer. Usual blast arrangements (not shown) supply blast to apertures C in the casings B, from the interior of which the blast passes through the grate apertures D into the bottom of the producer. Beneath the central aperture formed by the truncation of each grate is an ash table E, of the form usual in dry-bottom producers. Above each table and coaxial with each grate is a rotary scraper G, discharging the ashes therefrom, while tables and scrapers are enclosed in a hopper H, provided at its lower end with a discharge bell J.

CABLES FOR SHAFTS AND MINES.*

BY E. KILBURN SCOTT, A.M.INST.C.E., M.I.E.E.

(*Concluded from page 346.*)

Insulation.—Although shaft cables working at several thousand volts are the exception at present, they will come into more general use because of the tendency to generate power in large central stations. Such power is generally supplied at 3,300, 6,600, or 11,000 volts, and for main haulage and main pump motors, there is no reason why current at the full voltage should not be taken down the shaft. In one of the Durham pits, three-core vulcanised bitumen cables have been working satisfactorily at 6,600 volts for some years, whilst

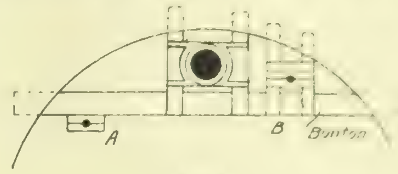


FIG. 6.

there are many mines where 3,300-volt cables are installed in the shaft. No doubt in time 11,000 volts will be used. One reason for using high-pressure shaft cables is that squirrel-cage motors are preferred for underground work on account of their simplicity, and when such motors of several hundred horse-power are used, the starting currents run to very high values. If the pressure drop caused by these large currents is not taken into consideration, it may happen that the pressure is insufficient to start the motor. A pressure drop of 100 volts is a loss of about 20 per cent. at 500 volts, but only 3 per cent. at 3,300 volts.

Solid Bitumen.—Solid bitumen cable is the name given to cable which has the conductors embedded in a solid mass of insulating pitchy material without any jute, or other fibrous binder. To a certain extent the name is a misnomer, because pure bitumen forms only a small proportion of the mixture,

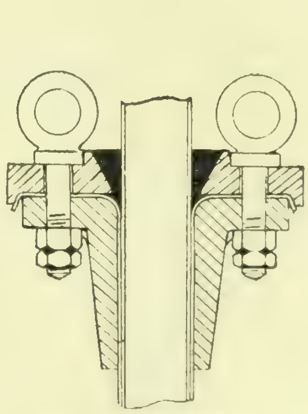


FIG. 7.—CORE SUSPENSION

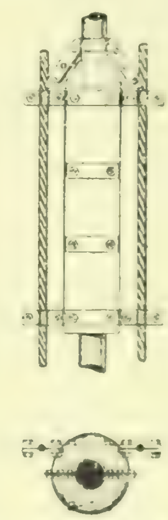


FIG. 8.—SUSPENSION WITH WIRE ROPES.

the component parts being cotton-seed pitch, Trinidad bitumen, and sulphur. The sulphur gives vulcanising action similar to that in rubber. After being worked up in many rollers like rubber, the pitch is squirted on to the conductors, which in some cases have been already covered with a separator of paper or impregnated jute. This mixture is used because pure bitumen alone is liable to crack and to allow the conductors to decentralise. Of course, all pitchy substances "flow" to an extent if the pressure is kept up in a definite direction for a long period, but by mixing in the cotton-seed pitch and sulphur, a consistency is arrived at which just gives sufficient elasticity to prevent cracking and at the same time prevent decentralisation at such temperatures and mechanical pressures as are usually met with in mines. The elastic pitch softens at about 120° Fah., and,

* Abstract of paper read before the Association of Mining Electrical Engineers, February 7th, 1913.

therefore, cables insulated with the material are not suitable for upcast shafts. One advantage of this form of insulation is that it resists ordinary pit waters. In bitumen cables it is customary to fill the interstices of the stranded conductors with waterproof compound so as to prevent moisture creeping along the wires. It may be of interest to mention that when cotton-seed pitch was first used the supply came from soap works, it being a by-product of that industry: but now the demand is sufficiently great for it to be specially made for cables.

Rubber.—Although rubber has been largely displaced by paper and bitumen for power cables, it has always held its own for lighting and for those heavier cables where flexibility is of special importance, as, for example, cables for portable machines, and for sinking shafts. Of course, the question of the use of rubber insulation depends on the supply, but by the introduction of rubber plants from the Amazon to Ceylon, the Straits Settlements, &c., future supplies are assured. Whilst the cultivated trees are young the rubber does not come up to the matured wild rubber of Para, but each year's growth will naturally improve plantation rubber. There are, in addition, possibilities before the synthetic process, and therefore the writer is of opinion that rubber will come into more general favour as an insulation for heavy cables.

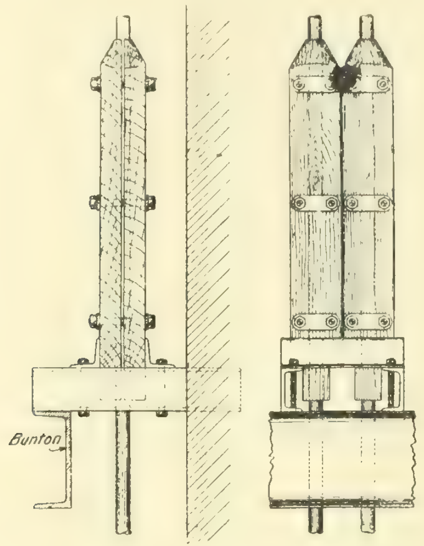


FIG. 9.

About three years ago the St. Helen's Cable Company hit upon the idea that the same mixture of rubber and various material of which wheel tyres are made, would also be an excellent mechanical protection for cables subjected to hard wear and wet conditions. This method of covering a rubber-insulated cable with a cab-tyre sheathing, as it is called, has been astonishingly successful, not only for trial cables, but for laying direct in the ground and for shot-firing wires, &c. The rubber and the silicious powder are in about equal proportions, and the mixture is squeezed on cold, under great pressure, by means of a screw. Vulcanisation of the rubber is carried out after the operation of covering the cable is completed. The cab-tyre rubber is not intended as an insulator; it is purely a mechanical protection, and its success as such appears to be partly due to a peculiar shielding action which the material has on the rubber particles. That it will do all that is claimed is shown by the remarkable way in which it stands up against hard wear and tear and chemical action, &c., when used for the tyres of vehicles. It appears to be the only type that will withstand the special conditions of chemicals from "made ground," and excessive vibration and constant movement due to heavy traffic.

One development which naturally suggests itself is the employment of tyre rubber for the protection of sinking cables. The insulation of such cables must necessarily be of rubber, and to follow this up with a protective coating of somewhat similar material is reasonable. A next step is the use of tyre rubber for cables which are permanently installed in shafts, and the writer believes it will be successful for that purpose also. Most shaft cables are supported by cleats which act as so many friction clutches, and it is easy to see that much less pressure will be required to hold a rubber-covered cable than to hold one that is armoured. Its high co-efficient of friction and ability to squeeze slightly when under compression makes rubber an ideal material where cleats are employed.

Bitumen insulation is especially liable to crack and perish just where the cable leaves the cleats, because at those points there is a considerable racking action due to vibrations. Paper insulation also depends very largely on the resin oil, and when such cables are cleated the oil may be squeezed out.

Paper.—Paper insulation has a distinct advantage over bitumen, in that there is no possibility of decentralisation. The conductors may therefore be worked at a higher current density, which means reducing the weight of the cable. Further, as the dielectric strength is much greater, it is a very suitable insulation for extra high tension. Against this, it has to be remembered that paper must have a covering to keep out moisture, and therefore what is saved in weight and size of conductors and insulation, is made up by the covering. Lead is usually employed for ordinary cables, but for shaft cables a sheathing of bitumen may be employed, the bitumen sheathing being mechanically protected by tapes and double braiding.

Paper-insulated cables for ordinary work, such as feeders to public electric supply, have as much resin oil as possible, and during manufacture the cable passes direct from the oil tank to the lead press. For a shaft cable this would not do, because the oil might flow down the cable and burst the lead sheathing at the bottom, as, in fact, did happen on one occasion. Therefore, when impregnating such cables the excess oil is allowed to drain off before the sheath is put on. Care must be taken to protect the cable ends to prevent moisture getting in, and consequently there is greater expense in boxes, sealing ends, &c., and in jointing, than with either bitumen or rubber-insulated cables.

Mr. Scholey informs the writer that the special insulation which goes under the trade name "Indestructible" consists of layers of papers, with a cotton or jute braiding, and the whole impregnated with red lead and linseed oil. Red lead seems at first sight an unlikely material for use in insulation, but there is no doubt that cables insulated in this way do resist chemical action and abnormal climatic conditions.

Lead-covered cables frequently have a thin copper sheath immediately under the lead, the object being to add to conducting power of the lead, so that in the event of a fault occurring, a heavy leakage current can flow without the lead being melted. Where there is a parallel path to earth, as when the cable is armoured and where work in a shaft is used, then there is no need for the copper. Lead is not a good material to use because it is so easily stretched during the operation of suspending the cable in the shaft.

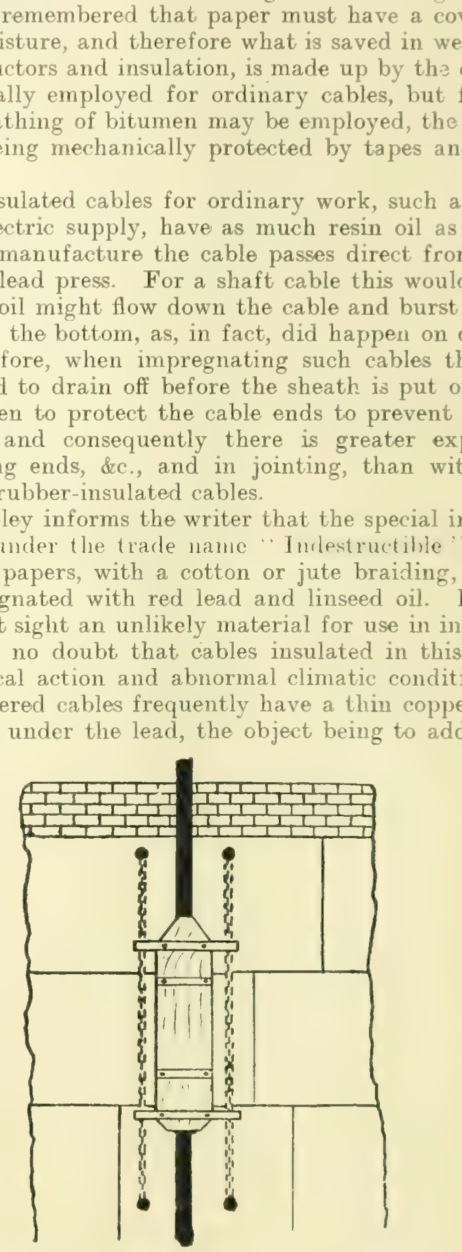


FIG. 10. CLEAT ATTACHED TO TUBBING BY CHAINS.

Jute.—At one time impregnated jute was frequently used as the insulation for low-voltage cables. It was apparently

satisfactory, for the writer has been informed of such a cable in the shaft of one of the Dortmund collieries 400 metres deep, which has been working satisfactorily for over 10 years. Nowadays, jute is used for worming with insulated conductors for the bedding between lead covering and armour, and for the protective covering outside the armour. The jute is either tarred or impregnated with an insulating and water-resisting compound. The choice between these two methods of treating the fibre depends to some extent on whether the armour is going to be left bright on the outside. If left bright the jute bedding underneath is tanned, but if the armour is to be treated with impregnated jute outside, then

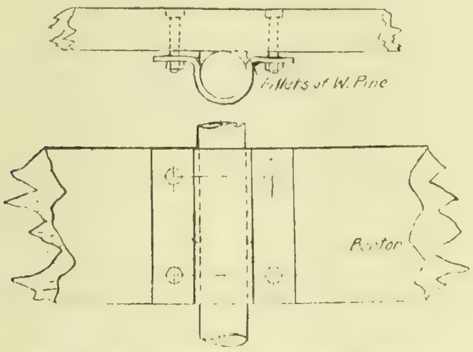


FIG. 11. IRON CLEATS AT LOCHGELLY COLLIERIES.

impregnated jute is used inside. The tanning of jute yarn consists in impregnating it with an aqueous solution made with cutch and hot water, but any agent, such as oak bark or sumach, can be used. The effect is similar to that obtained in the tanning of leather, namely, to render it rot-proof. When comparing weights of cables it is necessary to remember that if jute is used it may in time become saturated with water, and considerably increase in weight. From this point of view, jute is objectionable for shaft cables, especially seeing that at the same time as it becomes heavier it also tends to break down the insulation.

It is somewhat strange that jute should be practically the only fibrous material used for cables because other fibres are available. For example, coir yarn made from the fibres of the cocoa nut is a likely material. Coir yarn is practically incompressible, and is tougher and resists the weather better than any other vegetable fibre, as is well shown by the fact that the main ropes of ships' rigging are frequently made of it. In the loose state it is very much cheaper than jute, and even when plaited, although the plaiting is done by hand, it is also cheaper than manufactured jute. The plaiting is not very even, but that could be overcome. To ascertain the comparative value of this coir over jute, tests have been made. After being immersed in water for 48 hours, the amount absorbed by the plaited sample of coir was about 20 per cent. less than for jute, and the loose sample of coir absorbed about 15 per cent. less than the jute. After impregnation the plaited sample appeared to be only 10 per cent. better, but the loose sample was considerably better in the ratio of 8 to 34.

Armour.—Round wires in two layers are most commonly used. Double armour gives extra strength, and the increased area is useful for the earth return. Another reason for having two layers in the case of shaft cables which are suspended or cleated is that the cables do not then tend to turn either way, for unlike steel strip, the two layers of round wire are laid on in different directions. Steel strip is generally left plain, but wire is usually galvanised, and particularly so in the case of shaft cables, in order to resist the action of the water. Strip is not used for shaft cables. Segmental-shaped steel wires are sometimes met with, especially on the Continent. For shaft cables segmental steel wires appear to be better than round wires, because they give a more complete cover, and for a given sectional area less weight of steel is required. This is especially the case when the armouring is double. Where the armour is relied upon to support the cable, then segmental wires are best. To cover a certain diameter of cable, there are fewer wires to handle, and the labour charge is less, but the wire stranding machine requires a special lay plate with which to lay the wire at the proper angle. Possibly this accounts for most manufacturers preferring round wires.

Placing in Position.—There are several methods of getting shaft cables into position: (1) Lower the cable from a special winch at bank arranged to take the cable drum. (2) Suspend the drum in or under the cage, and pay out the cable as the cage descends. (3) Lower the drum to bottom of the shaft, fasten the end of the cable to the cage and haul up. (4) Run out the cable on the surface, attach one end to a locomotive and then lower it by moving the locomotive towards the shaft.

When the cable is placed behind buntons it must of necessity be lowered from the top. Also if it is unarmoured, it has to be lowered from the top and is temporarily lashed at intervals to a steel rope. By erecting two stagings at the top of the shaft, three rope lashings can be fixed simultaneously, and in this way the time occupied in lowering is reduced. The lashings are of spun yarn ½in. diam., and each tie is so spaced that it supports about 1 cwt. of cable.

When the drum is suspended under the cage, a plank brake is rigged up against one flange of the drum to prevent the loop of cable becoming long enough to revolve the drum and so run the cable off quickly. When the cable is for single suspension the drum is taken down the shaft and a suspension clamp is fixed to the end of the cable, by which it is attached to the side of the cage with chains. The cage is then raised to the top, drawing out the cable with it, the clamp being finally landed into its permanent position by chain blocks. All pulleys for the cable to pass over must be larger in diameter than the cable drum, say 4ft. diam., and they should also be so arranged that the cable is always bent in the same direction. Vee-grooved pulleys should not be used. After being fixed in the shaft a loop should be left at the bottom so that water may drip off clear of the junction box.

If the cable is to be fixed by cleats and there are no bearers or buntons already in the shaft, then they must be put in for the purpose. The cable cleats may be bolted against the front of the bunton as at A, Fig. 6, or they can

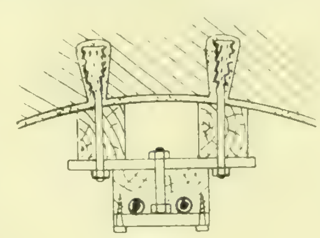


FIG. 12.

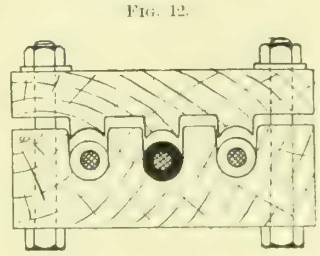


FIG. 13.

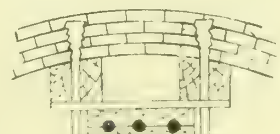


FIG. 14.

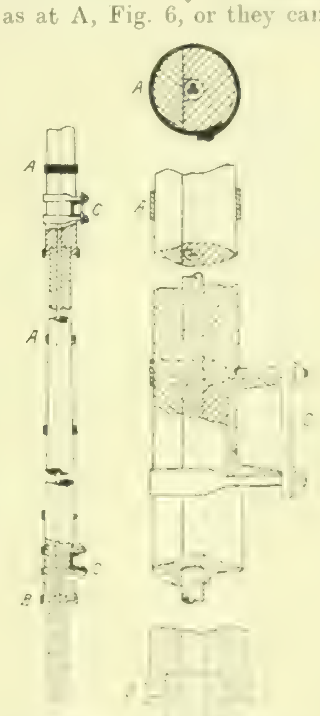


FIG. 15. [illegible]

stand on two small cross-bearers reaching from the shaft wall to the bearer, as at B. With the latter arrangement the cable has to be threaded behind the buntons from above and the cage cannot then be used. As a matter of fact, it is not always convenient for working the mine to have the cages held up until the shaft cable is installed, as is necessary when the cable drum is attached to the cage. At the same time it is most important that the work be thoroughly well done.

because a shaft cable cannot be got at at short notice as cables on underground roads can be.

Single Suspension.—The cone type of single suspension appears to have been copied from a method used in the Navy. An iron cone is passed over the armouring, and the outside wires bent over and taken down the outside of the cone. The smallest outside diameter of the cone must be sufficient to permit all the armour wires to lie side by side without overlapping. It is then fitted into the seating of a cast-steel bucket, and the latter is hung by chains from a girder across the top of the shaft. The space at the top of the cone is filled with bitumen compound to prevent corrosion. Such a suspension gives about three-quarters of the breaking stress of the armour, because it is practically impossible to so bend the wires that they all grip equally. As the armour is designed with a breaking stress of, say, eight times the weight of the cable, the factor of safety of the suspension is about six to one. The bolts and the chains must also be designed to give that factor of safety. With the heavier sections of galvanised wires it is difficult to bend the wires round the cone, especially so as to ensure that each wire takes its share of the load. This

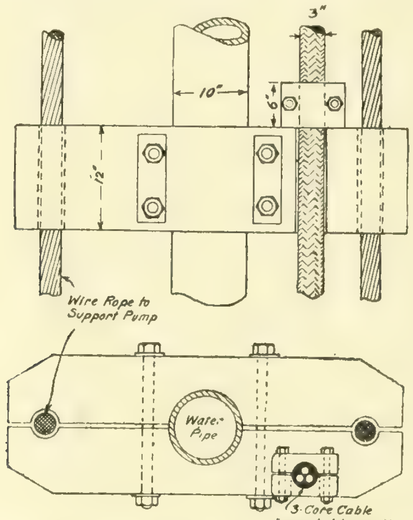


FIG. 16.—CLAMP FOR WATER PIPE AND SINKING CABLE.

is not the case with the design shown in Fig. 7, for there is no difficulty in bending the wires at right angles and gripping them all firmly by means of the top plate, which is held down by four bolts.

For the purpose of single suspension the steel armour wires must have a high modulus of elasticity, so that the elongation is as small as possible. This elongation really controls the weight that can be suspended, as it becomes dangerous long before the breaking stress safety factor becomes too low. The elongation is imparted to the insulation of the conductors, and if it is appreciable the insulation may be ruptured, and the cable cores will then endeavour to gain the necessary length by closing in on one another.

The single suspension method can only be used for moderate depths, for even when the strength of the steel armouring is ample as compared with the weight of the cable, there is an element of doubt as to how long it may remain so. Steel armouring is apt to corrode, especially near the top, and as the strength of a wire lies to a large extent in its outer skin, quite a small amount of corrosion quickly decreases its tensile strength. It should be noted that only the outer layer of armour is available for suspension, the inside layer going forward to connect to the earth-plate. Single suspension has the advantages that there is nothing for a falling object to strike against; also there are no places for lodgment of dust and slime. A cable can also be quickly placed in position by single suspension. For example, Mr. Bolton Shaw has instanced a case where a cable 300 yards long, weighing 3 tons, was fixed in about 4 hours.

Suspension by Wire Ropes.—In the method of suspension shown in Fig. 8, the shaft cable is clipped to two wire ropes which are hung permanently in the shaft, and the ropes may be anchored at intervals down the shaft to supplement the fastenings at the top. This method is very flexible, and offers less opportunity for the lodgment of dirt and slime than in the case of cleats. It is not good for hot shafts because the steel rope is more sensitive to variations in temperature than the cable.

Cleats.—Most shaft cables that have been installed in this country within present years have been fixed with wood cleats. The usual form of cleat is about 3ft. long, 12in. wide, and 6in. thick. A hole is bored through it lengthwise to the exact size of the cable. Then the block is sawn in half, and after the cable has been pressed into the groove, the ⅛in. taken out by the saw is sufficient to give the necessary grip. Elm and pitchpine are generally used. The resin in the pine assists the grip of the cleat on the cable and resists absorption of water. Oak is not suitable because of the tannic acid it contains.

Fig. 9 shows two cleats, 2ft. 6in. long, provided with three sets of ⅝in. bolts, with ⅜in. thick iron straps front and back. The bottom rests on two H or channel irons, which in turn are supported at one end by the bunton, and at the other by being let into the wall of the shaft. A triple cable cleat is sometimes fixed to the tubbing of the shaft by means of bolts. This has the advantage of lying closer to the side of shaft and requiring less cutting away of the shaft than is necessary where buntons are employed. The top of the cleat is chamfered off so as to reduce the lodgment of dirt and slime, &c., and un umbrella of sheet iron carries off the water and deflects falling stones. The cleats are so spaced that each one is loaded with about 10 cwts., and this usually gives a distance apart of 25 yards to 35 yards for fairly heavy cables. The fewer cleats the better, for it must be borne in mind that even when cleats are made 3ft. long they are liable to affect the insulation detrimentally by compressing it. Also at each end where the cable leaves the cleats there is liability of injury to the insulation, due to the cable vibrating when the cages pass up and down.

When an armoured cable is fixed by cleats it is practically the same as a solid bar from top to bottom, and anything striking it is firmly resisted. The most objectionable feature is that the cleats themselves may be struck by falling objects. Fig. 10 shows a method of fastening the cleat by chains, and it is better than fixing firmly to the side of the shaft or on buntons, because of their flexibility. Fig. 11 shows an example of an iron cleat as used at the Lochgelly Iron and Coal Company's pits. The shaft cables of the four pits consist of 0·3 sq. in. three-core low-tension 500-volt cable of the "Johnson & Phillips" solid-bitumen type, double-wire armoured and jute-served. The net weight of the cable is 40lbs. per yard, and as the cleats are fixed every 10 yards, each one has to carry about 4 cwts. In the Nellie and Mary Pits, which are 400 yards deep, the cables are in two lengths, jointed in a seam halfway down. It was necessary to fix the shaft cables between the buntons and the side of the shaft, and these being square pits, in many cases there was only a clearance between the bunton and the pit side of 4in. or 5in. The cable itself being 3·3in. diam., this necessitated the special type of iron cleat shown. Clearly an iron cleat for pressing the cable against a bunton can only be the width of the bunton, that is to say, less than a foot. As a cleat acts on the principle of a friction check, a short cleat has the disadvantage that the insulation has to be compressed much more than a long one. Also the co-efficient of friction of an iron cleat against an iron armouring is less than, say, wood against iron.

Casing.—Casing is usually made of pitchpine treated with Stockholm tar, the grooves being cut a little less than the size of the cable, so that the cables have to be lightly malletted into place. In this connection it is important to remember that when a cable is wound on a drum the inner layers may become flattened. Fig. 12 shows the method of fixing casing to the side of the shaft by means of rag bolts, and Fig. 13 shows a form of casing which has been used by Messrs. Callender's, in which the capping has projections to fit into the grooves. This method is more effective in keeping moisture from the cable, but is more expensive.

The original shaft cable installation at the Frickley Colliery of the Carlton Main Colliery Company, near Doncaster, has three 37/12 unarmoured bitumen cables. They are for 550-volt alternating-current, and in the upcast shaft, which is 670 yards deep. The casing is in 24ft. lengths, 12in. wide, and 2½in. thick, with lidding 1½in. thick. The cables are partly in the casing and partly in the lidding, which is fixed

to the side of the shaft by rag bolts, as shown in Fig. 14. At the top and bottom of the shaft, where the cable changes in direction, the casing has to be specially made to a curve of ample diameter, and great care has to be taken in fitting the lidding so that water may not get in.

The objections which are usually urged against casing are: (1) That during erection, the cable may be damaged by excessive malletting where the troughing is out of alignment, and also the cable may be damaged when fixing the capping; (2) in wet situations it is difficult to keep out water at the joints of the lidding, and especially between the various lengths; (3) the initial cost of sawn timber and bolts, &c., also cost of erection.

The writer has given considerable thought to the problem, and believes he has found a satisfactory solution in the use of split telegraph poles. The pole is sawn in two and one of the halves grooved. Then when the cable is in place, the two halves are secured by steel bands, as shown in Fig. 15, which are slipped over like bracelets and then driven down towards the butt. The two halves are thus closed in in much the same way as a cooper is able to completely close the joints between the staves of a barrel. Bolts and screws are done away with altogether. The poles would be erected with the butt end downwards, and the small end of the pole immediately below would fit into the butt end of the one above, as shown at B, B, Fig. 15. There is thus no possibility of an open joint between the various lengths, which is one of the causes of trouble with ordinary sawn casing. The poles are secured in the shaft by the very simple means of cutting "Gains" in the side, so that each pole is keyed, as it were, against the buntons. The poles are held to the buntons by steel straps, as shown at C, C.

The writer believes that casing fitted in this way would overcome the objections usually urged against enclosing the cables in timber. At anyrate, there can be no question that telegraph poles such as suggested would be a better mechanical protection than supporting cables in cleats. For example, if a tub should fall down the shaft, it would be glanced off by the pole without doing much damage, whereas a firmly cleated armoured cable would most likely come to grief. As the cables would not need any armour, advantage could be taken of the cheaper and lighter metal aluminium. The saving due to this and to the omission of armouring would much more than cover the expense of the casing.

There are many mines where, on account of bad water, armouring, or even separate wire ropes, are out of the question. The writer knows of a mine in New South Wales where the armour on a shaft cable was useless in less than six months. Mr. Chris. Jones also instances a colliery in this country where steel rope was used in a shaft as the earth return. Its conductivity became so bad owing to the water that a special copper cable had to be installed to act as the earth connection. There has been much talk about armouring as if it were a panacea for all trouble, but apparently it is not.

Preservatives. — Clearly the quality of the wood used for cleats and casing is an important matter, also the character of any preservatives that may be employed. Many preservatives have a detrimental action on metal and insulation. Some woods and some preservatives are more affected than others by the special conditions met with in mine shafts. These conditions include repeated heating and cooling, especially in the upcast shaft, where the temperature may be over 100° Fah.; also the action of water, for there is always water in a shaft. This water is partly pure, being rain or moisture in the atmosphere, and partly impure water from the various strata through which the shaft passes, and which water may be either acid or alkaline.

Creosote, which is the most commonly used wood preservative in this country, is quite impossible for wood in contact with electric cables; also with one or two exceptions all the other preservatives are forms of creosote or other chemicals which are deleterious to insulation, lead, and steel. One of the exceptions is the saccharine process of Mr. W. H. J. Powell, and as this process appears to be very little known, it may be of interest to describe it at some length. Sugar, especially beet sugar, is a simple, stable carbo-hydrate, incapable, in the absence of soluble nitrogenous matter, of nourishing septic organisms. It has a high boiling point, and has a greater power of diffusion through the wood than has water. In fact, the wood shows such a decided affinity for the saccharine solution that it readily penetrates to the centre without the use of pressure or vacuum.

The wood to be treated is placed in an open tank filled with the saccharine solution. As the temperature is raised, the air expands and escapes, and as the saccharine solution boils at a slightly higher temperature than water, the moisture in the wood is also gradually converted into vapour and escapes. The albuminous matter in the wood coagulates and is rendered inert, and in some measure this coagulation accounts for the strength of the wood being increased. During immersion, and especially while cooling, the solution penetrates to every pore of the wood, and after drying is not visible either as crystals or syrup, chemical analysis showing that it is held in molecular combination.

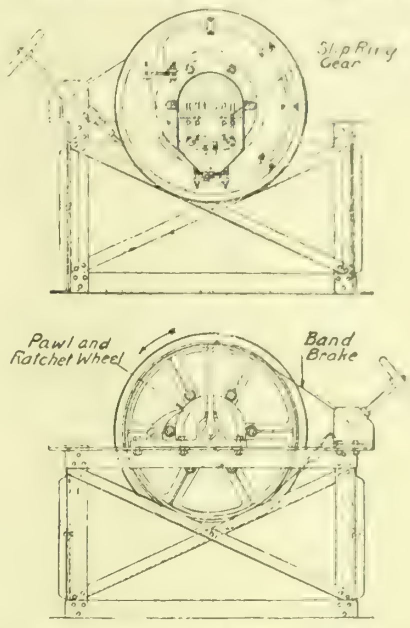


FIG. 17.—WINCH FOR SINKING CABLES.

When considering the question of using timber it is necessary to bear in mind that it may be attacked by fungi and insects. White ants in particular are a terrible pest in most countries where mining is carried on. Indeed, it may be said that over the greater portions of the British Empire, this pest has to be combated by engineers. Creosoting does not prevent destruction of wood by white ants because it does not penetrate far enough below the surface, and, as is well known, white ants always work along the inside of timber. Abrasions, cracks, nail holes, &c., are fatal to creosoted timber.

There is not the slightest doubt that a complete solution of the white ant trouble has been found in applying saccharine and arsenic by the Powell process. In Sydney, for example, the writer has seen wood treated by this process, used as troughing in which to lay electric feeders, and there is special significance in that fact, because white ants have been known to eat right through untreated wood troughing, the contained bitumen, the lead-covering, and the insulation of the cable. There is an entire absence of acid reaction, and the ability of Powellised wood to withstand changes of temperature and moisture is quite remarkable. This is borne out by some tests made at the Seacombe Preston Brick and Tile Works. They required for a special purpose timber which would not soften or warp when subjected to sudden and repeated changes of temperature and moisture. They found that untreated beech, elm, and pine softened, and that oak and ash warped. Also that the iron screws holding the pieces together corroded beyond further use in about 14 days. On the other hand, yellow pine treated by the Powell process stood up for over five years without softening, warping, or splitting, and with little, if any, corrosion of the screws.

In order to protect the cables and the wood, it is usual to paint them with preservatives, and those generally used are ordinary tar, Stockholm tar, and bitumastic enamel paint. There appears to be a consensus of opinion that ordinary tar will attack insulation, and that even Stockholm tar is not quite safe. The explanation of the various experiences with Stockholm tar is probably that those who found it satisfac-

tory took the precaution to boil it. This boiling reduces the volume by about 25 per cent., but it has the advantage of driving off the acids and water.

Before painting the cables, the surface must be thoroughly dried with hot sand, and such sand as sticks to the surface will help to hold the paint. To protect the cable from water during the painting operation, a tarpaulin sheet about 12ft. long is used. This is tied tight on to the cable at the top end, and a ring is arranged inside in order to spread the tarpaulin out clear of the cable. When the length has been painted the tarpaulin is lowered to the next position.

Sinking Cables.—A sinking pump is usually suspended by a continuous steel rope, one end being fixed at the surface. It is carried down the shaft, and, after passing under a grooved pulley attached to the pump frame, it returns to the surface, and is coiled on to the drum of a winch. Then to lower the sinking pump, some of the rope is merely uncoiled from the winch. Besides suspending the pump, these ropes also serve as guides for the rising water main. Wooden clamps are tightly fixed on to the piping at intervals, and holes are cut in them which leave just sufficient space for the ropes to pass through freely. The electric cable is also fixed to the wooden clamps, so that in the ordinary way the sinking cable is only loaded with its own weight for the distance from the top of the shaft to the first block. When pumping from a considerable depth the sinking pump generally raises water to an intermediate chamber, and the cable winch for suspending the pump is then placed at that point in the shaft. A cable cleated to the side of the shaft in the ordinary way carries current down to the winch.

Sinking cables differ from ordinary shaft cables in that they are constantly being moved, and therefore require to be much more flexible. Further, they generally have to withstand more wear and tear and the action of water, &c. It is probable that cables protected mechanically and from the wet by tyre rubber will be found as satisfactory as armoured cables. They will certainly be much more flexible and resist water much better. By placing the winch in one or more insets as the shaft descends the length of the sinking cable can be limited to that at which a cable without armour is feasible. The supply of current to the inset points would, of course, be by permanently fixed cable.

The sinking cable for Pease & Partners' Colliery at Thorne, near Doncaster, was made by Messrs. Callenders. It is a three-core cable insulated with pure and vulcanised rubber, with a vulcanised bitumen sheath and double wire armouring. The conductors are each 0·15 sq. in. area, and the pressure is 3,000 volts. An exactly similar sinking cable has been supplied to Tilmanstone Colliery, of the East Kent Colliery, near Dover. At this colliery three-phase current at 3,000 volts is transmitted from the surface to an inset at 600ft. by means of cable, which is cleated to the side of the shaft. In the inset, a winch is installed, and when the pump is drawn up for shots to be fired or other purposes, some of the cable has to be detached from the main cleats. This is done by having a notch cut in the side of the cleat, as shown in Fig. 16.

Fig. 17 gives details of the winch supplied by Messrs. Callender for raising and lowering the cable. The main from the source of supply is connected to slip rings, which are an electric connection to one end of the cable coiled on the drum. Where heavy and long lengths of cables are required, a worm-wheel gear is used in place of the ordinary winch handles, and an extra band brake attachment in place of the pawl and ratchet. The diameter of the drum must be such that when the pump is in the highest position, *i.e.*, when the cable is fully wound up, there are not more than three layers on the drum, otherwise the heating will be too great. It is usual to assist it by having ventilation ducts in the ends and surface of the drum. The cable is fixed to the drum by removing the armouring wires from the end, and forming a loop which is placed round a pipe. When the cable is hanging quite free in the shaft, its entire weight must, of course, not be allowed to hang on this loop, so a number of turns are left on the drum.

Earthing of the sinking cable armouring is frequently specified for the safety of the attendants, and for this purpose a fourth slip ring must be provided which is connected with the armouring, and the contact sliding on the fourth slip ring connected to earth. The switch controlling the pump motor is usually at the surface, and as it is necessary to be able to switch it out from the pump, auxiliary switch wires have a separate small cable attached to the wood blocks on the rising water main. As this cable must make the same upward and downward movements as the large power cable, a second small winch is required. It is important that the cables should go down at the same speed; also the cable must be slightly in advance of the pump, as under no circumstances must the cable be strained.

DUST EXPLOSIONS.

In consequence of the two serious dust explosions which occurred in November, 1911, at a provender mill in Glasgow and an oil cake factory in Liverpool a series of experiments has been carried out at the Home Office Experimental Station at Eskmeals by Dr. Wheeler, the chemist attached to the Explosions in Coal Mines Committee, with samples of all kinds of carbonaceous dust—so far as known to the inspectors—which are liable to be generated on premises under the Factory and Workshops Acts, with a view to determine their degree of inflammability and capacity to transmit explosions. The results of the experiments are given in a report by Dr. Wheeler, which was issued a few days ago. Experiments were made with 66 samples in all. The samples were not specially selected, but were in all cases ordinary samples taken by factory inspectors from beams, ledges, or other projections in the course of their inspections. Two methods of testing were employed—one for the purpose of discriminating between harmless and dangerous dusts; the other with the intention of ascertaining the temperatures at which inflammation of the dangerous dusts takes place readily. As a result of these tests it has been found possible to divide the dusts into three classes, viz.:—

Class 1.—Dusts which ignite and propagate flame readily, the source of heat required for ignition being comparatively small, such, for example, as a lighted match. This class includes sugar, dextrine (calcined farina), starch, cocoa, rice refuse, meal and sugar refuse, cork, unextracted soya bean, wood flour, malt, oat husk, grain (flour mill), maize, tea, compound cake, grain (grain storage), rape seed, cornflour, flour (flour mill), chicory, briquette, gramaphone record, and extracted soya bean.

Class 2.—Dusts which are readily ignited, but which for the propagation of flame require a source of heat of large size and high temperature (such as an electric arc), or of long duration (such as the flame of a Bunsen burner). They include Copal gum, leather, "dead" cork, cocoanut oil milling, rice milling, sawdust, castor oil meal, oilcake, offal grinding (bran), grist milling, horn meal, mustard, shoddy, and shellac composition.

Class 3.—Dusts which do not appear to be capable of propagating flame under any conditions likely to obtain in a factory; either (*a*) because they do not readily form a cloud in air, or (*b*) because they are contaminated with a large quantity of incombustible matter, or (*c*) because the material of which they are composed does not burn rapidly enough. These include organic ammonia, tobacco, spice milling, drug grinding, cotton seed and soya bean, bone meal, coal (foundry blacking), lamp black, sack cleaning, retort carbon, rape seed (Russian), blacking, grain cleaning, charcoal, foundry blacking, brush carbon, stale coke, plumbago, bone charcoal, and mineral and ivory black.

The dusts in Class 1 are arranged (roughly) in order of their inflammability. In this class sugar dextrine, starch, and cocoa are the most dangerous, sugar exceptionally so. Sugar ignites when projected as a cloud against a surface heated to below red heat, and when ignition has taken place, the flame travels throughout the dust cloud with great rapidity. The ignition temperature of sugar dust was found to be 805° C.

Of the dusts in Class 2 the samples of shoddy, being of a fluffy nature, did not readily form a cloud in air, but they contained a sufficient quantity of fine material to render them dangerous when in bulk. The sample of shellac composition contained over 60 per cent. of incombustible matter, but was inflammable. A reduction in the quantity of incombustible matter present would render it dangerous.

Of Class 3 the first 10 are all more or less readily inflam-

mable, but they showed no signs of being capable of propagating flame. The classification of these dusts as harmless refers, therefore, to the particular samples tested only. The remaining dusts in Class 3 can be definitely regarded as harmless materials.

The apparatus used in the tests is described in detail in the report. The various dusts are tabulated, and the ignition temperatures indicated. It is remarked that the latter are relative, and refer only to the particular set of experimental conditions employed. For the sake of comparison the ignition temperatures of most bituminous coal dusts, as determined in the same apparatus, are given as lying between 1,000° and 1,100° C. So far as possible the different dusts (all of which were dried during one hour at 107° C.) were obtained of the same degree of fineness by passing through a 200-mesh sieve, but in some cases this was not possible owing to the fluffy nature of the substance, while in other cases the sample received contained no such fine dust. The report observes that the ignition temperatures in such cases have no relative value, and the experiments made serve only to show whether or not the substance is dangerously inflammable. The following are a few specimen results, with the remarks thereon: —

Lamp black.—No ignition. Could not be sieved.

Rape seed.—Ignition temperature 1,050° C. (probably lower, but no more dust available). Did not sieve; sample too small.

Sawdust.—Ignition temperature 970° C. Twenty per cent of sample passed through sieve.

Blacking.—No ignition. Seventy-five per cent. of sample passed through sieve.

Starch.—Ignition temperature 1,035° C. Eighty per cent. of sample passed through sieve.

Foundry blacking.—No ignition. The whole of sample passed through sieve.

Briquette dust.—Ignition temperature 1,090° C. Ninety per cent. of sample passed through sieve.

Flour.—Ignition temperature 1,060° C. Ninety per cent. of sample passed through sieve.

Charcoal.—No ignition; a few sparks only. Ninety per cent. of sample passed through sieve.

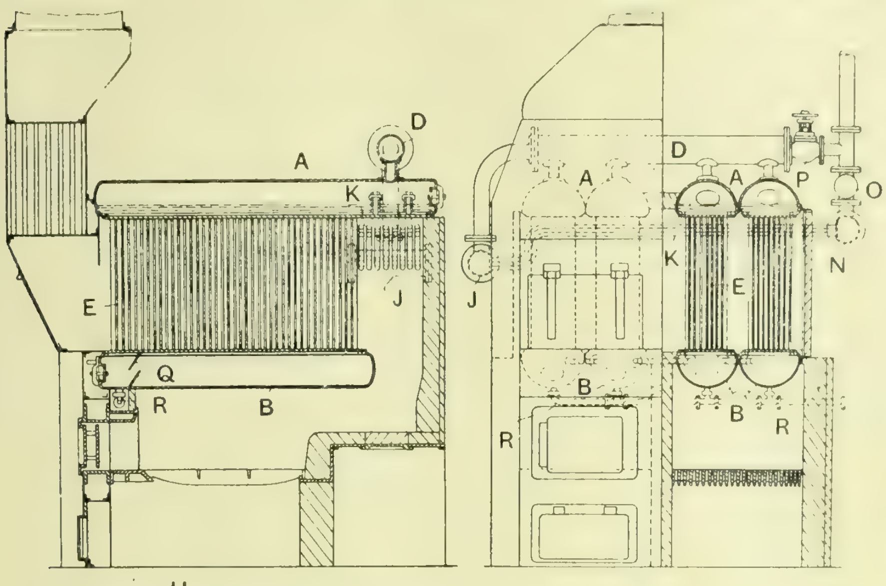
Coal (foundry blacking).—No ignition; a few sparks only. Seventy per cent. of sample passed through sieve.

Plumbago.—No ignition. Ninety-five per cent. of sample passed through sieve.

Bone charcoal.—No ignition. The whole of sample passed through sieve.

HOWDEN'S WATER-TUBE BOILER.

We illustrate herewith a design of water-tube boiler, fitted with superheater and feed water heater, the invention of Mr. James Howden, 195, Scotland Street, Glasgow. The boiler comprises upper drums A and lower drums B connected together by the water tubes E. The upper drums are connected by means of short branches to an equalising steam pipe D. The space between the inner elements is wider than the space between the inner and outer elements, on account of the brickwork separating the two furnaces. A partition H is provided, between the elements in each furnace, so as to prevent passage of the gases from one furnace to the other when one furnace is not being utilised. The saturated steam is led from one end of the collecting pipe to a header J, which is flattened at one side to receive the superheating tubes K, which pass through a door at one side of the combustion chamber, and, after being bent upwardly, as shown, pass beneath the bottom plates of the upper drums A, thence through a door on the opposite side of the combustion chamber to a header N. A stop valve O is fitted on the header N, and connected to the main steam supply pipe, and a valve P is connected to the collecting pipe and to the main steam supply pipe. This valve P is of sufficient size to supply all or nearly all the steam evaporated by the boiler, and is used in conjunction with the valve O for the purpose of giving a supply of steam more or less superheated. The lower drums B are supported at their front ends, where they are protected from the action of the hot gases, and within these lower drums at the front ends thereof are diaphragm plates Q, which cause the front tubes E to act as down-comers, and also ensure collection of sediment. Connecting the bottom drums B at the front ends is a common feed-water pipe R, which may also be used as a common blow-off. At the rear of each combustion chamber are water boxes S (Fig. 2), disposed horizontally and of triangular form in cross section. Fitted to these boxes are tubes U, preferably of less diameter than the upright water tubes E of the generator. The tubes U are staggered, and are so placed that they touch, or nearly touch, each other vertically, and thus form a water wall at the rear of each combustion chamber. The boxes are placed above the level of the fire grate, and are protected more or less from the heat by means of brickwork. Feed water is led to the lower boxes by a pipe V, provided with a non-return check valve, and flows through the tubes U into the upper drums, the feed water being heated in its passage through the tubes.



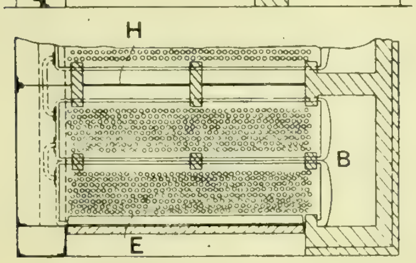


Fig. 1.—Howden's Water-tube Boiler.

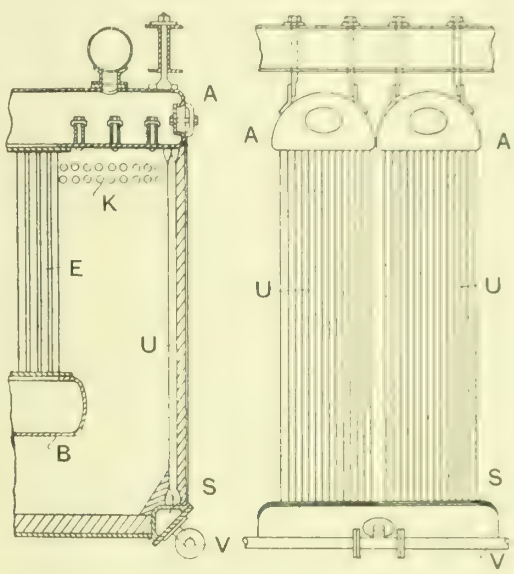


Fig. 2.—Howden's Water-tube Boiler.

Convention on Foundry Practice.—The "Association Technique de Fonderie," is organising a Convention and an Exhibition in connection with foundry practice. They will be held at the Ecole Nationale d'Arts et Métiers at Paris from the 26th to the 31st of May next. The Convention will be opened on May 27th, when the president of the Association will welcome the delegates. There will then be a discussion of the results of a competition on the "Practical Study of Foundry Cupolas." The Exhibition will also be formally opened. A number of interesting papers are down for reading and discussion.

CORRESPONDENCE.

Modern High-speed Gearing.

To the Editor of "The Mechanical Engineer."

Sir,—After having carefully read the paper delivered by Mr. Hubert Thorne, before the Rugby Engineering Society, as reported in *The Mechanical Engineer* of March 7th, 1913, we think that some of Mr. Thorne's statements are open to criticism, and we trust that a few remarks from our quarter will be of interest to your readers. Had Mr. Thorne only treated the subject of staggered double helical teeth, we would have refrained from criticising a paper which, on many points, is very interesting. But Mr. Thorne refers to machine-cut helical gears in general, and, for this reason, one would expect his paper to give some, if not all, of the special advantages of the continuous helical tooth. As a matter of fact, the latter system of gearing is only shown in the paper, as a kind of obscure background, in front of which the staggered tooth principle would appear conspicuously. It is true, one of the chapters is headed "Relative Merits of Staggered and Continuous Teeth," but, notwithstanding this promisingly impartial title, the author draws a comparison between the two systems of double helical gears which is extremely one-sided, not to say more. It is obvious from this chapter that Mr. Thorne is exclusively interested in staggered teeth, for he wants us to believe that the latter have no defects at all, and that continuous teeth have nothing but disadvantages! Even the gap of the staggered teeth which is necessary by reason of manufacture, becomes an object of praise, and the very fact that continuous teeth are not interrupted in the centre is actually called a serious drawback! Surely this is far from being a scientific method of criticism.

Mr. Thorne claims for the system he is advocating the advantage of being free from possible defects of step by step division, but he forgets to mention that the real source of inaccuracies is the worm wheel, which directly drives the blank to be cut. In his recent lecture on "Mechanical Gearings for the Propulsion of Ships," the Hon. Sir Charles A. Parsons has dwelt at great length on this point. It must not be forgotten in this respect that, for an equal cut of the hob and of the end-mill, the number of revolutions of the worm wheel is much more considerable for the staggered teeth. Consequently the worm wheel inaccuracies are of no importance for the continuous teeth, whereas they give great concern to those interested in staggered teeth. The author is particularly emphatic about the fact that hobs can be ground without altering their cutting shape, owing to being machine relieved, but he forgets to say that hobs, for the same reason, cannot cut teeth of accurately true section (which would only be obtained if the number of teeth of hobs were infinite). As a matter of fact, staggered teeth have a section which is a succession of small flats, and not an unbroken curve, as is the case for continuous teeth. Mr. Thorne declares that, for staggered teeth, both pinion and wheel are cut with the same hob. We suppose he means the same form of hob, for it is obvious that at least two tools (one for each half of the tooth) have to be used for either the wheel or the pinion. In this respect continuous teeth score undoubtedly, as only one end-mill is required to cut the whole tooth.

With regard to wear of end-mills and consequent alteration of the section of the continuous teeth, this criticism would be worthy of consideration if a finishing end-mill were not used after the roughing cutter has cut practically all the metal which is to be taken away. Therefore, the function of the finishing end-mill is simply to remove any unevenness left by the roughing cutter, and consequently to nullify the possible effects of wear of the latter. Besides, the greatest care is given to the manufacture and grinding of *our* end-mills, which, everyone will admit, are much less difficult and less costly to produce and replace than hobs.

With regard to the question of wear in machine-cut helical gears, we had expected some interesting data, but we were surprised to see that Mr. Thorne had simply stated a few somewhat sweeping generalities. For instance, we read in the paper that "the proportion of double helical gears should be controlled entirely by consideration of wear." Now we can say from our experience of the last 12 years, that these considerations are binding only in *some* cases, and that in most cases, if we calculate the continuous double helical gears for strength and for silent and efficient running, the coefficient of wear is satisfactory by way of consequence. It is only when the pressure on the teeth and the number of revolutions of the pinion are extremely high that wear is a prevalent factor in the design of the gears.

Mr. Thorne also says that, acting on considerations of wear, the manufacturers of staggered toothed gears introduced considerably finer pitches than had hitherto been used. We cannot help remarking that this is making a virtue of necessity. It is a well-known fact that hobs should preferably be of small diameters. The reason is that for hobs of large diameters the angular speed would have to be considerably reduced in order that the peripheral speed of the tool should be a reasonable figure. Consequently, the cost of cutting would become very great. Furthermore, although an increase of face is, for reason of strength, the result of a reduction of pitch, it may be said that it is also adopted by the staggered gear makers, in an endeavour to compensate the great loss of strength and rigidity caused by the gap in the centre of the teeth of their wheels. On the other hand, there is no reason to suggest that continuous machine-cut helical gears cannot be cut with very fine pitches if necessary, and on the strength of this fact we fail to see how Mr. Thorne can assert that the permissible minimum diameter of a pinion is *much* less with staggered than with continuous toothed gears.

The velocity of 1,200ft. per minute, above which, says Mr. Thorne, machine-cut helical gears should always be fitted in oil cases, seems to us a comparatively low figure, as with continuous helical teeth we only advise the use of oil cases (which materially increase the cost of gearing) when the peripheral speed is above 1,600 revs. per minute. We also contend that the problem of wear is less difficult to solve for our gears than for others, because our machine-cut helical teeth, having a theoretically true section and not being interrupted in the centre, run with absolute continuity and are free from bending. They can negotiate extremely high speeds without noise, and as there is no back-lash between the teeth, shocks which occur in other gears, and which contribute to their wear, are completely avoided.

We may say that very large faces have their disadvantages. There is always a chance of them not bearing on their full length, and if, owing to unsatisfactory erection, one tooth bears only on a part of its width, the possibility of breakage would be greater on account of the fine pitch than if there is a normal proportion between face and pitch. In cases where the wheel or pinion would be overhung, a very wide face would be more likely to cause trouble than a small one, on account of the resultant weight or pressure being applied farther from the bearing. On the other hand, it is evident that, when a large centre distance is fixed, the pitch cannot be reduced (with a resultant increase in the width of face) outside of certain limits, for the consequence would be that the number of teeth would become very great, which would complicate the cutting and make the erection a difficult matter. This is a point which cannot be too much emphasized, as the satisfactory running of machine-cut double helical gears greatly depends on their accurate fitting. Finally, we wish to be allowed to say it is surprising that such statements as criticised above should be found in a paper which, from its title, is supposed to deal with a general subject. These statements might easily mislead the audience if they were not so obviously an advertisement of a particular make of gearing.—Yours faithfully, S. ROGER.

(Engineer to Andre Citroen & Co.)

27, Queen Victoria Street, London, E.C.
April 2nd, 1913.

Australian Railway Gauge.—The conference of Australian railway experts, which was called to consider the necessity for a uniform gauge and to decide which gauge it would be best to adopt, has recommended that the adoption of a uniform gauge for Australia is desirable at the earliest possible moment. It has also decided that the standard should be either 4ft. 8½in. or 5ft. 3in., neither of which, it was considered, had a decisive advantage over the other. The conference has adjourned in order that figures for the cost of conversion to either gauge may be accurately worked out. When this has been done the conference will make a final decision.

INDUSTRIAL AND TRADE NOTES.

A Large Forging.—What is supposed to be the largest ingot ever forged has just been completed at the Grimesthorpe works of Messrs. Cammell, Laird, & Co. The forging, which weighs 150 tons, measures 23ft. 6in. in length, and is 80in. across the flats at the large end, and is intended for special Admiralty requirements.

Personal.—The Carlisle Electricity Committee have selected Mr. Frederick Walter Purse, of Watford, for appointment as electrical engineer at Carlisle, at a commencing salary of £500 a year. Mr. Purse has been chief electrical engineer to the Watford Urban District Council, and is 35 years of age. There were 148 applicants.

Iron Ore in Cape Colony.—The Mines Department in South Africa has, we learn, received information of very promising deposits of iron ore between Kimberley and Preiska. It is understood that the existence of the deposits has been known for some time, but no attempt has been made to develop them, their importance having only recently been realised.

Eight-hour Day for Winding Enginemen.—The Home Secretary gives notice that on the 1st inst. he made General Regulations under Sections 57 and 86 of the Coal Mines Act, 1911, as to the hours of employment of winding enginemen, and that he has prescribed June 30, 1913, as the date after which, under Section 57 (3) of the Act, a winding engineman may not be employed for more than eight hours in any one day except as provided by the General Regulations. Copies of the regulations will shortly be placed on sale.

Extension of Harland & Wolff's Govan Yard.—Messrs. Harland and Wolff, of Belfast, have determined upon an important extension of the shipbuilding yard on the Clyde recently acquired by them. They have purchased approximately $7\frac{1}{2}$ acres of additional land adjacent to their shipyard at Govan. It is not yet known definitely to what purpose the ground will be put, but it is surmised that marine steam engine and boiler works will be laid down. This would make the works on the Clyde completely self-contained, and obviate the necessity of sending ships to Belfast to be fitted out.

British Coal Output in 1912.—A White Paper issued on Saturday last states that the output of coal during 1912 from mines under the Coal Mines Act was 260,567,552 tons. This total excludes dirt, and allowing for dirt, which has been included in previous returns, the output shows a falling off when compared with 1911 of 9,012,783 tons, this being due to the coal strike. The number of persons employed at mines under the Coal Mines Act was 1,689,165, an increase of 21,952. The decrease in the output of coal is at the rate of 3·32 per cent., and the increase in the number of persons employed at mines under the Coal Mines Act is at the rate of 2·06 per cent.

Railways in China.—The Chinese Government has, we learn, now decided to construct an important railway in the Yangtse Valley which will connect the Pukow terminus of the trunk line with Sinyang, an important station on the Pekin-Hankow Railway 170 miles north of Hankow. The concession for this railway was granted to a British corporation in 1898. The length of the proposed line will be 260 miles, and it will run through thickly populated country. The estimated cost is £2,000,000. The Government has appointed Mr. Bourne as chief engineer for the line. Mr. Bourne, who has had exceptional experience on many important railways in China, will leave for Pekin shortly to begin the survey for the line.

Tannett, Walker, & Co., Ltd.: Receiver Appointed.—The trustees for the first mortgage debenture stock of Tannett, Walker, & Co., Ltd., of Hunslet, have felt compelled to take steps to protect the interests of the stockholders by appointing a receiver of the works and property of the company. Mr. J. W. Close, chartered accountant, of Leeds, is the receiver. The firm is one of the best known in Leeds, and has long been noted for the construction of steel-making machinery. The authorised capital of the company is £350,000 in £10 shares, £50,000 of these being 5 per cent. cumulative preference shares, and the rest ordinary shares. In 1911 the whole amount had been allotted, fully paid, to the vendors and their relatives. The firm has employed several hundred hands.

Mineral Production of Canada.—According to a preliminary report issued by the Canadian Department of Mines, Ottawa, the mineral output in 1911 was somewhat restricted owing to long extended labour disputes, and the largest previous production was in 1910, compared with which that of 1912 shows an increase of over 24 per cent. This progress is all the more satisfactory because it is evidently due to a widespread and substantial development of the country's mineral resources. A substantial increase in price in most of the metals, which took place early in the year and continued throughout it, had a very important bearing on the year's operations and contributed largely to the increased value of the output. A feature of particular interest during the year has been the continued and extended development of ore reserves. The satisfactory results from these operations point to much greater annual outputs in the future. Extension of ore smelting and refining facilities and in a number of cases special improvements in methods of practice have also been important factors in the year's operations.

Mining Legislation.—At a meeting of the Yorkshire branch of the National Association of Colliery Managers, held at Wakefield on Saturday last, Mr. Frank H. Waterhouse, of Denby Grange Collieries, the new branch president, delivered his inaugural address. He said they were living in a time when legislation was poured thick and fast upon the mining community. During the past year they had had to administer the Mines Act, 1911, the Minimum Wage Act, the National Insurance Act, and also a few orders in Council by way of supplement to the Mines Act. As to the future, they had the general regulations to face. Most of them were admirable in their purpose, but others, unless they were redrafted, were entirely the opposite, and not likely to attain the object for which they were framed. He thought colliery managers as a body were firmly convinced that it was time the Government called "Halt!" with regard to legislation for mining. Legislation was, no doubt, meant to protect life and limb, which was a most sacred object, and the managers accepted it as such. He considered that a fair amount of credit for the reduction of accidents during the last few years was due to the high standard set up by colliery managers themselves.

Co-partnership.—The Companies (Co-partnership) Bill was read a first time in the House of Commons on the 1st inst. The main objects of the Bill are, first, to enable companies to adopt co-partnership in cases where they would otherwise be debarred from doing so, either by their private Acts of Parliament or their articles of association; secondly, to set out in the form of a schedule a model scheme of co-partnership for their voluntary adoption; and, thirdly, to provide that such model scheme shall ordinarily be a condition for granting statutory power to new companies to raise capital, though, of course, without attempting to fetter the discretion of Parliamentary Committees in individual cases. Under this scheme certificates of partnership in the objects of the company and a share in its surplus profits are to be granted to all persons in its regular employment. It is provided that the standard rates of wages shall be taken to correspond with a standard return of 5 per cent. on all paid-up capital, and when the return is higher than 5 per cent. the employe becomes entitled to a bonus calculated at one-twentieth of his existing wages for every extra 1 per cent. paid in dividend. There are also other provisions that in the case of very large bonuses being payable that trustees should be appointed, as in the very successful instance of the South Metropolitan Company, who should hold and invest part of the bonus for the benefit of the workpeople. There are further provisions as to the appointment of these trustees and as to the appointment of directors and as to the settlement of matters in dispute.

A Non-corrosive Iron Alloy.—A practically non-corrosive iron alloy has recently been put on the market under the trade name "duriron" by The Duriron Casting Company, New York. The alloy, it is claimed, is quite resistant to ordinary rusting, and is only slightly attacked by alkalies and acids, with certain few exceptions. It closely resembles cast iron, but it is some 10 per cent. lighter in weight. It has shown an average ultimate strength of 70,000lbs. per square inch in compression, with 15,000lbs. tension; the elastic limit is very close to the ultimate strength, as the metal is somewhat more brittle than cast iron. It melts at 2,250° Fah., and is a much better conductor of heat and electricity than cast iron. The actual composition of the metal is not announced, though the makers admit that some 10 per cent. or more of silicon is to be found. The only way of working this alloy is by casting and grinding, as it is about one-half harder than cast iron, it cannot be machined by the older processes. The abrasive found most successful with it is carborundum. Shrinkage in casting is found to be about $\frac{3}{16}$in. to a foot, compared with the $\frac{1}{8}$in. ordinarily assumed for cast iron. It has been found that cupola practice is so important that "duriron" is not recommended to general foundrymen, although the makers will sell the alloy in pig form. Up to the present, large plane surfaces have not been successfully cast, the principal trouble being in shrinkage cracks. The metal is particularly suitable for use in acid pipe line fittings, valves, cocks, receptacles, &c., in centrifugal pumps, steam siphons, and in substitutes for earthenware fittings of chemical works, powder and celluloid factories.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Regulating rotary compressors. Grun, and Pokorney & Wittekind Maschinenbau Akt. Ges. 28507.
Internal combustion engines. Douglas. 28519.

1912.

Surface condensers. Parsons & Cook. 3933.
Boring, facing, recessing, and analogous machines. Munro. 4026.
Rotary motor. Borton, Ross, Metzgar, & Metzgar. 4289.
Driving belts. Mellin. 6380.
Starting mechanism for explosion motors. Robin. 6484.
Apparatus for forcing and raising liquid and semi liquid substances. Goodwin & Lewin. 6502.
Water-heaters. Dicker. 6678.
Derricks. Hutchinson. 6698.
Metallurgical furnaces. Morgan Crucible Company, Davison, and Harvey. 6808.
Valves. Patterson. 6816.
Internal-combustion engines and variable speed gears. Comery. 6876.
Internal combustion engines. Gerlich & Vogt Engines, Ltd. 6880.
Internal combustion engines. Gerlich & Wiffen. 6881.
Means for vaporising benzine. Romanoff. 6897.
Internal combustion engines. Tacchi. 6916.
Ship construction. Horne. 7013.
Acetylene gas generators. Bell. 7022.
Steam traps. Paterson. 7072.
Automatic starting devices for internal combustion engines. Burt & Matthew. 7156.
Apparatus for indicating and recording the flow of liquid over weirs or through orifices. Paterson. 7172.
Gearing for converting rotary into reciprocating motion. Weekes and Absolom. 7306.
Apparatus for raising or forcing liquids. Siemens Bros. Dynamo Works, Ltd., and Kieffer. 7336.
Means for converting reciprocating into rotary motion and vice versâ. Williams. 7384.
Motor road vehicles. Catling. 7465.
Tinning metals. Bowen. 7945.
Automatic inlet valves. Stupecky. 8258.
Internal combustion engines. McKechnie. 9307.
Cranes, derricks, and shear legs. Culling. 9633.
Machines for casting metals. Alston. 10172.
Expansion joint for fuel economisers and heating apparatus. Downes & Moverley. 10199.
Fluid-pressure change-speed gear. Maxted. 11171.
Gas-distributing devices for internal-combustion apparatus. Siemens Bros. Dynamo Works, Ltd., and Kieffer. 11246.
Distributing means for fluid-pressure engines. Lafitte. 11835.
Removing salt deposits from the walls of evaporators. Reimer. 11909.
Sluice or gate valves. Blakeborough & Broadhead. 11991.
Shaft grinding machines. Ward, and Gear Grinding Machine Company. 12034.
Clutch operating and similar mechanism. Triumph Cycle Company, and Franklin. 12836.
Steam boilers and settings therefor. Brown. 13008.
Friction clutches. Constantinescu. 13106.
Steam generators. Jacobson. 13221.
Safety detaching hooks for mine cages. Barker. 13294.
Manufacture of high carbon steels. Williams. 14130.
Adjustable burners for liquid fuel. Schaffer. 14551.
Elastic-fluid turbines. Warwick Machinery Company (1908), and Naylor. 15482.
Inverted-tooth type of driving chain. Hans Renold, Ltd., and James. 15502.
Power-operated boats or vessels. Berry. 17065.
Internal-combustion engines. Riker. 17499.
Friction clutches. Saver Clutch Company, Hewitt, and Drake. 17983.
Rotary lubricating device for internal-combustion engines with revolving motor cylinders. Marks. 18994.
Valve gear for internal-combustion engines. Fried Krupp Akt.-Ges. 19227.
Drill chucks. Boer. 19332.
Controlling gear for winding engines. McCabe & Macdonald. 19826.
Internal-combustion engines. Constantinescu. 19915.
Burners for liquid fuels. Schnabel. 20833.
Steam generators. Chantiers et Ateliers Augustin Normand. 21842.
Driving belts. Dew & Azulay Syndicate, Ltd. 22004.
Driving gear for internal combustion engines. Lurie. 22033.
Safety devices for mine cages. Nesztor. 22269.
Centrifugal pumps. Lobnitz. 23817.
Ball bearings. Hart & Almtelt. 24792.
Means for operating furnace dampers. Matter. 25456.
Open hearth suction gas producers. Crossley & Fielden. 26127.
Aerial machines. Société Aeroplanes Morane-Saulnier. 26263.
Heating of furnaces and kilns. Georgs-Marien Bergwerks-und Hutten Verein Akt. Ges. 26695.
Milling cutter or abrasive wheel profile generator. Brown and Bostock. 27263.
Method of eliminating or reducing the external corrosion of steam generators provided with heat non-conducting governings. Wild & Kolkmann. 27285.
Double-acting ball thrust bearings for horizontal or inclined shafts. Fried Krupp Akt. Ges. Germaniawerft. 27506.
Starting device for explosion engines. Mowe. 29024.

1913.

Conveyors. William Beardmore & Co., and Clark. 32.
Case-hardening or cementation materials. Rudge-Whitworth, Ltd., and Heathcote. 185.
Cupola furnaces. Anderson. 2289.
Derricks. Hutchinson. 4590.

ELECTRICAL, 1912.

Timing devices for making and breaking electric circuits. Hatfield. 6404.
Vapour electric apparatus. Leblanc. 6655.
Distance-operated mechanisms and signals on electric supply systems. Handcock, Dykes, & Duddell. 6716.
Electric transmitting mechanism for marine engine governors. Rumolino. 6828.
Automatic electric circuit breaking arrangements. Möller. 6990.
Signalling by means of electro magnetic waves. Chambers. 7242.
Protective devices for the conductor rails of electric railways. Merz & Redman. 7591.
Slip-ring collector devices for electrical instruments and machines. Denny & Edgecombe. 8640.
Electric coupling or connection fixtures. Trood & Dale. 9909.
Vacuum electric water heater. Mann. 12367.
Means for selectively operating one or several of a series of electrical devices. Schmid. 14121.
Electric induction heater or furnace. Helfenstein. 14164.
Protective devices for electric circuits. British Thomson-Houston Company. 16708.
Apparatus for reproducing undulatory electric currents. Schiessler. 18655.
Contact devices for controlling points or signals on electric tramways. Weenen, Stoffels, and vander Sprenkel. 19160.
Spark plugs. Thompson. 20248.
Automatic electrically-operated elevators. Liljeblad & Aktiebolaget Elevator. 23918.
Production of high frequency currents for use in wireless telegraphy and telephony. Thompson. 24937.

1913.

Means for regulating the output of dynamos. Tattersall. 1205.
Electrical resonance apparatus. Handcock, Dykes, & Duddell. 5307.
Differentially wound compound dynamos. Kettering. 5545.

METAL QUOTATIONS.

TUESDAY, APRIL 8TH.

Aluminium ingot	95/- per cwt.
" wire, according to sizes, &c. ......from	112/- "
" sheets " " ...... "	120/- "
Antimony ......£31/-/- to	£33/-/- per ton.
Brass, rolled	8¼d. per lb.
" tubes (brazed)	9⅝d. "
" " (solid drawn)	8⅝d. "
" " wire	8¼d. "
Copper, Standard	£68/5/- per ton.
Iron, Cleveland	65/7½ "
" Scotch	71/7½ "
Lead, English	£17/7/6 "
" Foreign (soft)	£16/17/6 "
Mica (in original cases), small	6d. to 3/- per lb.
" " " medium	3/6 to 6/- "
" " " large	7/6 to 11/- "
Quicksilver	£7/10/- per bottle.
Silver	27 3/16d. per oz.
Spelter	£24/-/- per ton.
Tin, block	£218/10/- "
Tin plates	14/- "
Zinc sheets (Silesian)	£28/-/- "
" (Stettin; Vieille Montagne)	£28/2/6 "

The Mechanical Engineer.
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Edited by
WILLIAM H. FOWLER
Wh. Sc., M.Inst.C.E.

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The Kinetic Effects of Crowds.

THAT crowds of people are capable of exerting serious kinetic effects requires no demonstration, as they have occasionally produced disastrous consequences, but the matter has not hitherto received much analytical or experimental treatment. Architects and others concerned in the design of structures subject to moving loads of human beings have usually been content to take the accepted load of 160lbs. per square foot as a static effect and provided for stresses consequent on movement by a more or less liberal allowance in the factor of safety according to the circumstances. The absence of experimental data gives interest to a paper which has just been presented to the American Society of Civil Engineers by C. J. Tilden, recording some tests with a view to ascertaining the kinetic effects arising from sudden changes of posture. These were made with some half-dozen different individuals ranging in weight from about 110lbs. to 230lbs. Each individual was placed separately on a platform scale, their dead weights noted, and also the increases they exerted upon the scale beam in rising suddenly from a crouching to a standing posture, as well as from a sitting to a standing posture, and also the maximum increase they were capable of exerting by "jouncing" or jerking downwards, the feet in no case leaving the scale platform. As would naturally be expected, the kinetic effects of these three kinds of tests varied with individuals, since the essence of the results obviously depends upon the muscular capacity of the actor. In standing up from a crouching posture the lowest increase of weight recorded was 15 per cent., and the greatest effect, which, curiously enough, was attained by the heaviest man, was as much as 80 per cent., while the average increase of eight individuals was 66 per cent. In suddenly standing up from a chair on the weighing machine platform the increases in weight were even greater than those recorded in standing up from a crouching posture. As in the previous case, however, the results were not uniform, and showed the greatest increase

with one of the heaviest of the seven men tested, and the average increase recorded was 79 per cent. The effect of "jouncing" or jerking on the scale, as might be expected, was greater than in the two other tests, though we should scarcely have anticipated the increase actually recorded. With none of the five men tested was it less than 132 per cent., while one recorded 236 per cent., and the average was 174 per cent. In other words, the motion of jerking imparted a downward pressure equal to 2¾ times the static weight. Although this latter result is not one which a crowd would or even could concertedly effect, for it would be difficult for individuals to act in unison, it is nevertheless interesting. The downward pressure caused by suddenly rising from a chair is, of course, an effect such as might be produced collectively by an audience rising suddenly, and the fact that downward pressure may in this way be increased by some 80 per cent. beyond the static load is a fact worth noting. Efforts were made by Mr. Tilden to obtain some idea of the horizontal forces exerted by a man in walking. The magnitude of these obviously depends upon the man's weight and speed and the greater the force expended in urging him forward the greater the backward thrust, action and reaction being of course equal and opposite. The force obviously is not uniform, since the movement of the centre of gravity of the subject is not in a horizontal line, but in one more or less wavy. Into the reasoning we need not enter in detail, suffice it that with a man weighing about 160lbs. the accelerating or retarding force, which would be more or less of a pulsating character, amounted to about 80lbs. or 90lbs. when walking at a speed of about four miles per hour. It is not easy, however, to co-ordinate a single experiment of this kind with the collective action of a crowd, except in special cases, though a body of soldiers marching in step would be a practical illustration and its potency for setting up vibrations is recognised, the breaking of step during the passage of a bridge by infantry being well known. Although the results of Mr. Tilden's tests may not be sufficiently exact to warrant any dogmatic statement as to the loads which should be provided for in dealing with the possible effects of motion in a crowd, they do roughly indicate that provision should be made, its precise magnitude being a matter for the individual engineer to determine in any particular problem.

The Trend of Invention.

THE figures given in the annual report of the Comptroller-General of Patents are interesting, as an indication not only of the general trend of the lines along which inventors are working, but of the directions in which public needs are most pressing, and therefore most promising to those who can successfully meet them. Taken as a whole, it would appear from the figures as if there was a slight falling off in inventive activity, since rather fewer patents were sealed in 1912 than in the two immediately preceding years, but this is probably more apparent than real and due, we think, to the greater stringency exercised by the Patent Office in respect to claims arising out of the system of search respecting anticipation that is now practised, for, although sealed patents were fewer, both applications and specifications were more numerous than in 1911. For several years the most important prominent group of inventions have been those relating to the motor-car and allied industries, and there does not appear, from the number of inventions taken out, to be any slackening, for the number last year was 25 per cent. in excess of the previous one. The trite adage that "necessity is the mother of invention" is reflected in the fact that a large portion of those relating to this group have reference to the problem of adapting the use of heavy hydrocarbon oils to replace higher-priced petrol in motor-car practice. The loss of the "Titanic," as might naturally be expected, has bent many minds upon the problem of saving life at sea and suggested quite a crop of mechanical devices for the speedy and safe lowering of boats or the detaching of safety rafts in cases of emergency. To the same disaster, we suppose, must also be attributed a number of inventions proposed for detecting the proximity of ice at night or in a fog, or for enabling a wireless distress signal to be received even though the operator be off duty. We don't know whether the Insurance Act and the outcry against its stamp-licking duties has acted as a stimulus to inventive activity, and accounts for the great increase in patented appliances for the damping and affixing of adhesive stamps. Large emoluments can hardly be expected from devices of this kind, though a fortune awaits the inventor of a machine which will pay the contributions.

THE CORROSION OF IRON AND STEEL.

THE 68th ordinary meeting of the Faraday Society was held at the Municipal School of Technology, Manchester, on Friday, April 4th, conjointly with the Manchester Section of the Society of Chemical Industry, when a general discussion on "The Corrosion of Iron and Steel" took place. The chairman was Dr. Gilbert J. Fowler.

An Electrolytic Theory on the Corrosion of Iron.—In this paper by Mr. Bertram Lambert, M.A., it was shown that a simple and natural development of the ideas of Faraday on electrolysis would give the foundation of a satisfactory theory of the corrosion of iron. Commercial iron was always heterogeneous in character, and, when a piece of such metal was placed in an electrolyte like water, the electrically different parts—whether the potential differences be due to impurities or to different forms of the metal—tended to set up an electric current between them, with the passing into solution of the metal at the relatively electropositive points. There was no doubt that iron was, practically speaking, insoluble in water, in vacuo—at anyrate chemical tests would not show the presence of iron in solution even after long periods. But it was generally agreed that iron must pass through a process of solution before rusting, and therefore oxygen must alter the conditions in such a way that iron could pass into solution in water in its presence. Oxygen probably played two different and distinct functions in the rusting of iron: (*a*) It helped the iron to pass into solution in the water by electrolytic action, probably by oxidising the film of hydrogen at the electronegative points—a non-conducting film which would, unless removed, reduce the strength of the current to a negligible value. Since iron only goes into solution by the passage of an electric current, so long as this film, which was formed the instant the iron was put in the water, persisted, no appreciable quantity of iron could dissolve; (*b*) the oxygen produced ferric hydroxide (rust) from the dissolved iron. The ferrous ions produced when the iron passed into solution could not be oxidised to ferric ions by molecular oxygen. They first combined with the hydroxyl ions, always present in water, to form undissociated ferrous hydroxide, and this was then oxidised to ferric hydroxide by the oxygen. The properties of chemically pure iron were shown to give very substantial support to the theory.

The Electrolytic Methods of Preventing the Corrosion of Metals.—This subject was dealt with in a lecture by Prof. W. W. Haldane Gee, M.Sc., B.Sc. He showed that the corrosion of metals could be lessened or prevented in two ways: (1) By connecting the metal to be protected to a more electropositive metal, so that a primary cell was produced; (2) by making the metal to be protected the cathode in an electrolytic cell supplied by an external electrical pressure. Various types of primary cell arrangements that could be employed in practice were classified. The efficiency of the cell for protection would depend on the current density at the cathode, and this would be controlled by the resistance of the cell and the effective voltage. The importance of overvoltage in determining the effective voltage was discussed. The history of Sir Humphry Davy's application of zinc and iron protection for the prevention of the corrosion of the copper sheathing of ships and

subsequent inventions for the protection of condensers and pipes were detailed. The patents of Harris and Anderson, in which aluminium alloys were used for the prevention of the corrosion of condenser tubes, were shown to be primary cell methods. In the case of the use of zinc in boilers was involved a knowledge of the electrolytic resistance of the boiler waters and the effective voltage at temperatures from 150°-200° C., concerning which there was great need of experimental data. The amount of zinc used in some marine boilers was as great as from 400lbs.-600lbs. of rolled zinc per annum. If the zinc was efficient in producing electrical currents then the average current might be from 17 to 25 amperes. It was obvious that such currents would be obtained much more economically by the use of a dynamo. The direct use of electrical currents had been the basis of a number of patents. Those of Mr. Elliott Cumberland were especially described. Iron anodes were placed in the water of the boiler, which latter was made the cathode. A low voltage of supply provided by a small motor-generator was used. The method had proved effective not only in preventing corrosion, but also in removing scale from the heating surface and preventing its formation. Experiments carried out at the Manchester School of Technology had shown that the current densities necessary to protect iron, copper, and other metals from the corrosion of fresh and salt water were of low value, and hence in the cases of boilers and condensers the annual cost of the electrical energy required was a small item. The chief cost would be in the renewal of anodes. Harris and Anderson had also applied electrical currents for the prevention of the corrosion of condensers. They found that a condenser with a cooling surface of 1,025 sq. ft. required only 2 volts and 2 amperes, and the special anodes used by them cost from £3. 5s. per 1,000 sq. ft. per annum. The use of electrical currents might also be applied in chemical works to prevent the corrosion of metallic screens and vessels from acid liquids. The lecture was illustrated by experiments and lantern slides.

The Nature of Overvoltage.—The author of this paper, Mr. J. T. Crabtree, M.Sc., said that overvoltage may be regarded either as the excess of the anodic or cathodic decomposition voltage of a dilute acid with a given electrode over that for platinised platinum, or as the excess of the back electromotive force set up as an electrode (anode or cathode) after polarisation over that set up by a platinised platinum plate under identical conditions. This back electromotive force was determined by alternately polarising an electrode and measuring its single potential difference by means of a potentiometer, alternate connection between the latter and the primary circuit being made by means of a rotating commutator. Overvoltage was affected by the time of application and current density of the polarising current, the nature of the electrolyte and electrode employed, and by the thickness of the latter. Since these factors also affected the back electromotive force of platinum, a comparison electrode was employed consisting of a thin deposit of platinum on Jena glass, the back electromotive force of which was constant with time. The overvoltage of a metal was taken as the difference between the back electromotive force set up after an application of the polarising current for 30 minutes at a given current density, in $\frac{N}{10}$ acid, and that set up by the above electrode under similar conditions. It was probable that overvoltage was simply a manifestation of the difference between the rate of production of ions at the electrode and of the combination of these to form complexes. Probably after being discharged the ions passed into a metastable condition and gave rise to a back electromotive force. The catalytic activity of the electrode was probably an important factor as affecting this velocity of reaction, and the difference in catalytic activity of various metals under different conditions of texture, temperature, &c., would explain why the overvoltage varied largely with different metals under different conditions. Overvoltage might be of importance in the case of the corrosion of a metal as either: (*a*) Having a tendency to retard the deposition of hydrogen or oxygen on its surface, which might tend to assist or prevent corrosion. (*b*) By setting up a high back electromotive force which would diminish the effect of a decomposing current in cases of corrosion due to electrolysis. (*c*) By assisting or preventing the solution of a metal. The condition that a metal may dissolve in an acid and evolve hydrogen was given by the relation

$$\text{e.m.f. of metal} - \text{back e.m.f. of hydrogen} > \eta$$

where η = overvoltage of metal. If η was large no solution of the metal could occur. This was apparent with galvanised iron, where, owing to the overvoltage of the zinc, very little solution of iron took place, the latter assuming the overvoltage of the external metal. In view of the absence of any suitable factor to indicate the tendency of a metal to corrode, future experiments might indicate a parallelism between the overvoltage of a metal and its corrosion factor.

Dr. W. Rosenhain, F.R.S., read a paper entitled "Note on a Specimen of Ancient Iron from Ceylon." The reading of the papers was followed by a long discussion. A number of specimens of corroded metals was exhibited.

SAFETY EXPLOSIVES IN MINES.

A PAPER on "The Testing of Safety Explosives," by Prof. Lewes was recently read before the Royal Society of Arts. Referring to the revised list of explosives issued by the Home Office, he characterised it as a praiseworthy desire on the part of the authorities to bring our tests into line with those of other countries, and to make the explosives used absolutely safe. There was a danger, however, that in so doing the authorities were running a risk of opening the door to greater dangers than now existed. Experiments had illustrated the complexity of the subject, and had shown that variations existed in different testing stations, and that these were due to a large number of factors, some of which were perhaps not even yet known. The only true test of the safety of mining explosives was the practical one of use in coal mines over many years, and when tons of the material had been used and millions of shots fired under every condition conceivable in practice without a single accident being traceable to its legitimate use, such an explosive held a certificate of safety that no series of tests under empirical and artificial conditions could ever give it. In the English permitted list there were several such explosives perfectly satisfactory, but under the new conditions their place would be taken by explosives so feeble in character that great difficulty would be found in ensuring complete detonation of the charge, while the mineowner, saddled by the Act of 1912 with the purchase of all explosives used in his mine, would find that the cost of explosives for doing the same amount as before would be practically doubled. It seemed to him absolutely wrong to reject 17 years of experience gained under mine conditions and to follow other methods unless statistics had shown that per million tons of coal won our mining explosives had given rise to greater loss of life than those used abroad. The practical conditions in use were so widely different from those of the tests that the personal factor of care in use became of enormous value, and he was convinced that a reliable and careful shot-firer, blessed with commonsense, was a greater protection than any tests, rules, and regulations that could be framed. For this reason he viewed with suspicion anything tending to lessen personal responsibility. He hoped that before the new regulations came into force in December, the points that had been raised would be very carefully considered.

Cutting Speeds and Bearing Pressures of Machine Tools.—Mr. E. P. Bullard, jun., of the Bullard Machine Tool Company, in the course of the discussion on a paper on "Machine Tools" presented before the Cleveland Engineering Society, mentioned a cut taken on steel, said to be 0·40 per cent. carbon. The chips came off red, the speed was over 400ft. per minute, and the material cut like wood. "I have frequently seen in our own shop," he said, "speeds of 300ft. on finishing cuts preparatory to grinding. The turning of steel castings is, of course, a more difficult problem, but speeds of 65ft., 70ft., 80ft., and 90ft. per minute are possible." Regarding the limits of pressure per unit of area which he allows in bearings, Mr. Bullard said: "We may try to keep within 25lbs. per square inch with a maximum of 50lbs. We may sometimes run over that on account of the difficulty of calculating pressure. The ordinary boring machine of our design is probably running at less than 10lbs. per square inch. We try to maintain very low pressure, but that is possible in machine tools which would not always be possible with other machines."

A COMPARATIVE TRIAL BETWEEN THE TRIPLE EXPANSION ENGINE AND GEARED TURBINES IN CARGO STEAMERS.*

BY C. WALDIE CAIRNS, M.SC.

THE secretary having invited the author of this paper to lay before the Institution the results of a comparative trial recently carried out under his supervision, between a cargo steamer fitted with geared turbines and one fitted with triple expansion engines, the author is pleased that with the consent of the owners of the steamers in question he is able to comply with your secretary's request. The contractors concerned in the building of the ships and machinery also courteously assented to the publication of the results, and have put at the disposal of the author much information which he is certain will add to the interest of the paper. The steamers in question are the "Cairngowan" with triple engines, and the "Cairnross" with geared turbines. Both are the property of The Cairn Line of Steamships, Ltd., of Newcastle. The "Cairngowan," completed late in 1911, is looked on—by her owners at anyrate—as a good example of the larger class of tramp steamer, with machinery and boilers of a good commercial standard for the attainment of a reliable 10 knots sea speed, with such economy of fuel as can be attained with relatively little complication of outfit.

When—early in 1912—the directors of the Line decided to order another steamer of similar type, it appeared advisable for the author as their consulting engineer to consider carefully whether he should recommend them to repeat the usual triple expansion engine. It will be remembered that for some time previous to that the air had been full of rumours as to the great things that might be expected from the oil engine in marine practice, and some creditable performances by that prime mover had already been reported. The true position had not yet been disclosed by the very interesting and useful series of papers, read before this Institution by Sir Charles Parsons, Mr. E. L. Orde, and Mr. A. C. Holzapfel, in April, 1912, which so clearly set out the comparative economical possibilities of the oil engine, the geared turbine, and the gas engine, as compared with the usual triple-expansion marine steam engine. Prior to the publication of these papers and the excellent discussion to which they gave rise, and without such full consideration as these papers stimulated, the view that the next step in advance might well be the adoption of the geared steam turbine had recommended itself to the directors of the Cairn Line. It appeared at that time that the oil engine still to some extent entailed "a leap in the dark," what with its mechanical troubles and the high price of its fuel, whilst the marine gas engine and gas producer were even less tried than the oil engine; at the same time either of these, it appeared possible, might emerge from its "infantile diseases" before a steamer —then new—should have attained a scrap-heap age, so that fuel economy might become more and more essential in competition as time went on. With boilers still indispensable, the geared steam turbine was therefore chosen as giving promise of good economy of steam and fuel, with less complication than is entailed with the usual means to that good end—quadrupling and superheating. Careful feed heating and judicious use of vacuum are usually added to the two means just mentioned, but it will be recognised that the steam turbine offers superior possibilities regarding these two, as compared with the reciprocating engine. Information was by that time general as to the economy attained by the first geared turbine steamer "Vespasian," and her records showed that with more fully loaded turbines even better results might be expected. Her gearing, too, had shown that it could be relied on under the "rough and tumble" of a ship's work at sea. Sir Charles Parsons, too, and his firm, had shown their faith in this system by putting it into the two cross channel steamers then building for the L. & S.W. Railway, the s.s. "Normannia" and the s.s. "Hantonia." At that time, however, they had not completed their trials.

Whilst the "Cairnross" was the first ship of her type to be built to take geared turbines, it will be understood that the grounds for the expectation of good results were excellent. One has only to realise how the high-speed steam turbine has put the large reciprocating steam engine out of the market for power station work to understand that the successful application of gearing—enabling high speed (and therefore economical) turbines to be coupled with a suitable sized propeller for ships of cargo-carrying class may work a revolution in marine practice. Until the combination of a reduction gear between the turbines and the propeller had been put into successful use, marine turbines, at anyrate in steamers of small speed and power, had never been capable of being designed to give expectation of a steam economy equal to that attained in the high-speed turbines used for similar power on shore. As the friction loss in the gearing is claimed to be only 1½ per cent. to 2 per cent. it will be at once understood that there is little to charge to the account

TABLE I.—*Comparison of Ships and Machinery.*

	S.S. "Cairngowan" Builders: Messrs. W. Doxford & Sons, Ltd.	S.S. "Cairnross." Builders: Messrs. W. Doxford & Sons, Ltd.
1. Type	Part awning deck (poop long bridge and f/c.)	Complete shelter deck.
2. Date of completion	November, 1911	January, 1913
3. Reg. tonnage	4,015 gross, 2,560 nett	4,016 gross, 2,513 nett
4. L (b.p.) × B. ext. × d. mld.	370′ × 51′ × 27′ 9″	370′ × 51′ × 27′ 9″
5. Draft on trial, for'd	23′ 1¼″	23′ 6¼″
6. ,, ,, aft.	23′ 8¼″	23′ 10¼″
7. ,, ,, mean	23′ 4¾″, leaving Cardiff.	23′ 8¼″, leaving Cardiff.
8. Displacement on trial	9,891 tons	9,950 tons
9. Block coefl. at trial draft	·784	·779
	BOILERS.	
10. No. and pressure	3 single ended, 180 lbs.	3 single ended, 180 lbs.
11. Diam. of boilers	14′ 9″	14′ 9″
12. Length of boilers	10′ 6″	10′ 6″
13. Heating surface, total	6,823 sq. ft.	6,823 sq. ft.
14. Furnaces, and int. diam.	9′ × 3′ 5″	9′ × 3′ 5″
15. Length of bars	4′ 9″ (trident)	4′ 9″ (trident)
16. Draft, and tube diam.	Natural; 3¼″	Natural; 3¼″
17. Funnel top above bars	About 77′	About 77′
18. Grate area (bars)	145 square feet	145 square feet
19. Bridges	Cast iron (Sturrock)	Cast iron (Sturrock)
20. Machinery	Single, triple-expansion inverted direct-acting. Cyls. 24″, 40″, 66″ dias. Stroke, 45″ Ratio L.P. H.P., 7·55	One high pressure, one low pressure, high-speed turbine geared to single main shaft. Ratio 26·2.
21. Condenser	Usual marine type forming part of framing.	Separate circular type
22. Cooling surface	2,563 square feet	square feet
23. Machinery and condenser built by.	Messrs. Wm. Doxford & Sons, Ltd.	Messrs. Parsons Marine Steam Turbine Co., Ltd.
24. Pumps	Air, circulating, feed, and bilge pumps driven by main engine as usual These feed pumps deliver to —	All independent, viz., Weir's dual air pump, centrifugal circulating pump, single cylinder bilge pump, single cyl. oil pump, one Nichols' feed pump drawing from Hotwell (float control) delivering to
25. Feed heater	Weir's contact heater	Nichols' contact heater
26. Hot feed pumped by	One Weir's feed pump	One Nichols' feed pump
27. Heat obtained from	Steering engine, feed pump and ash hoist exhausts, L.P. steam chest, and evaporator vapour.	Steering engine and all auxiliary exhausts & evaporator vapour.
28. Steering engine	Wigham's 8½″ diam. × 9″ stroke with piston valves, "Economic" valve cut out for trial.	Rogers' 8″ diam. × 12″ stroke with flat valves.
29. Propeller	Loose bronze blades, cast iron boss.	Loose bronze blades, cast iron boss.
30. Last painting of bottom	At Rotterdam, Jan. 1913.	At Sunderland, Jan. 1913.
31. Nature of paint	Usual one coat each of anti-corrosive and Anti-fouling composition, same maker.	

* Paper read before the North east Coast Institution of Engineers and Shipbuilders, March 28th, 1913.

of the gearing as an offset against the increased economy of the turbine over the reciprocating engine, provided, of course, experience as to durability proves satisfactory.

Before proceeding to an account of the trial a general description of the ships and their machinery is submitted in Table I. It will be noticed from this table that the two ships themselves are almost identical in essential characteristics as far as this trial is affected. In fully loaded condition (summer draught) a difference exists arising from the fact that the "Cairnross" owing to her complete shelter deck, is allowed some inches deeper immersion than the "Cairngowan" in view of which the lines of the "Cairnross" were fined slightly from those of the "Cairngowan." The trials taking place in February, the "Cairngowan" was run at her correct winter draught, and the "Cairnross" was loaded to $3\frac{1}{2}$ inches deeper than the "Cairngowan" to compensate for the slightly fined lines of the former vessel. Freight was therefore sacrificed in the case of the "Cairnross" for this voyage in order to obtain a valid comparison without calculated corrections. It should be here stated that sacrifices were made in other directions in the elimination of differences between the two ships, and in some of these the turbine machinery undoubtedly lost some of its superiority. Among these sacrifices the author would specially indicate the following:—

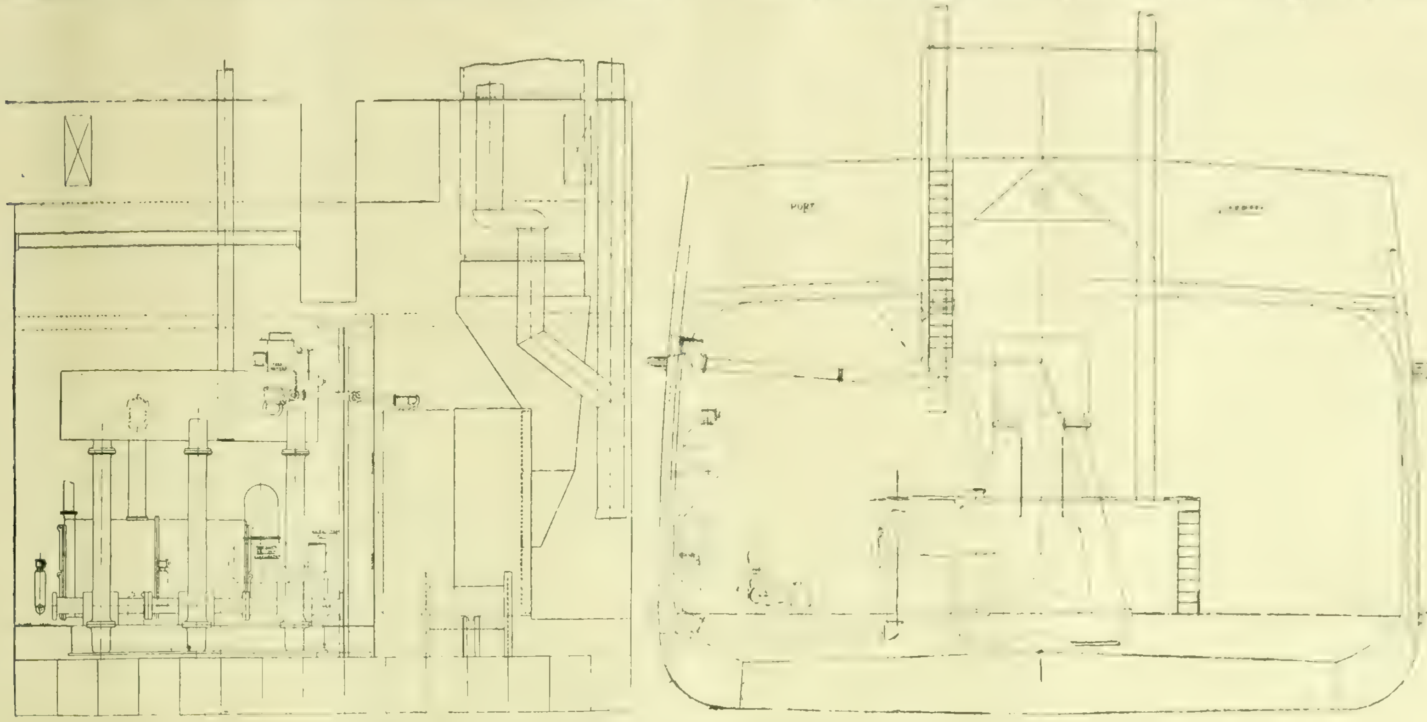
(1) The boilers were identical in the two ships. In view of the quite sufficient boiler power in the "Cairngowan," the boiler power in the turbine ship was evidently at least 15 per cent. too great for the purposes of the trial, entailing excessive radiation losses, as well as excessive weight of boilers and water.

(2) The boiler pressures were kept alike—180lbs. This is unnecessarily high for economy in turbines, and undoubtedly leads to increased radiation losses, increased loss in temperature of uptake and unnecessary extra weight of boilers.

(3) The propellers, tunnel shafting, and thrust blocks were identical in the two ships. No doubt in view of the steady turning moment and absence of racing with turbine machinery, the shafting might have been reduced in diameter even with the same propeller. Probably, too, in the interests of the turbine, of the gearing, and weight, the propeller diameter might have been reduced without loss of advantage in economy, in the turbine ship, with an increase of speed of revolutions of the propeller, and either a higher speed of revolution of the turbines or a lower ratio of reduction in the gearing, either of which would have been an advantage.

It will be noticed from Table I. and from the trial results that the "Cairngowan's" machinery is arranged with an efficient feed-heating system. To further indicate what relative economy this ship's machinery should show, it may be stated that the high-pressure valve is of the piston type, with Lockwood & Carlisle rings. High-pressure and intermediate-pressure pistons also have Lockwood & Carlisle's rings, and the lower-pressure piston is fitted with the usual broad ring and "coach springs." The intermediate-pressure slide valve is of the completely balanced type made by Messrs. Andrews and Cameron, and may be described as a rectangular piston valve in an adjustable casing. The high-pressure and intermediate-pressure piston rods are packed with a cast-iron rectangular ring packing, with no wedge action, and are therefore subject to comparatively little friction.

The general arrangement of the "Cairngowan's" machinery is shown in Figs. 1, 2, and 3. The "Cairngowan" had already done about 14 months ordinary work in River Plate, Black Sea, and Eastern trades: before proceeding on trial all main cylinders, pistons, and valves were examined by her own staff and representatives of her builders, and were found

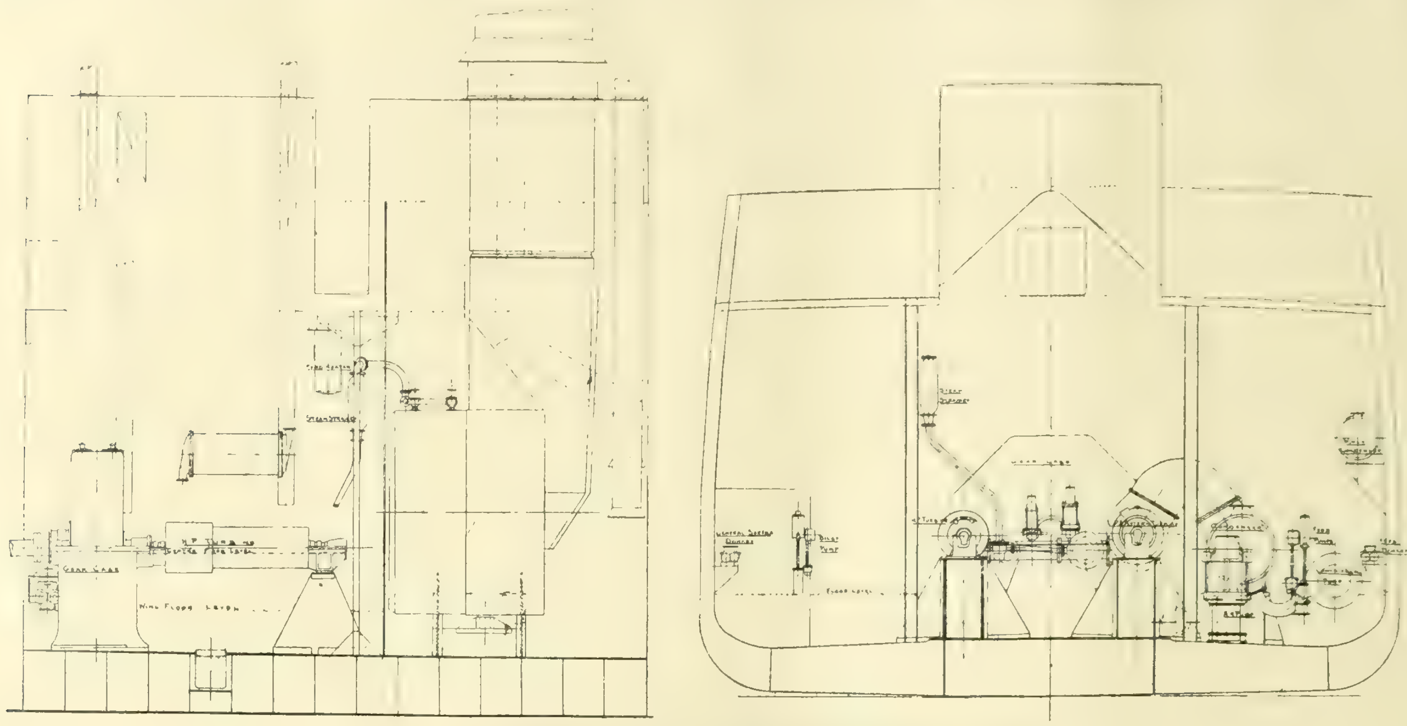


FIGS. 1 AND 2.—ARRANGEMENT OF RECIPROCATING ENGINES, S.S. "CAIRNGOWAN."

FIG. 3.—ARRANGEMENT OF RECIPROCATING ENGINES, S.S. "CAIRNGOWAN."

in good condition. Since last dry-docking (Rotterdam, January 15th, 1913) she had run from Rotterdam to London, lain in Thames four days, and run to Cardiff, where she lay 14 days.

The "Cairnross" since drydocking had lain four days in South Dock, Sunderland, run in ballast from Sunderland to Cardiff, and lain 12 days in Cardiff. The condition of the skin of these ships may therefore be taken as identical. They were painted with similar paint. The main machinery of the "Cairnross" consists of two reaction turbines in series. These are arranged one on each side of main line of shafting, and each is connected by a flexible and sliding coupling to a pinion shaft; each pinion shaft is carried on three bearings, and between these bearings and pinion teeth are cut on enlarged parts of the shaft. The general arrangement of the "Cairnross" machinery is shown in Figs. 4, 5, and 6. The teeth are spirally cut, and as the spiral on forward pinion on each side is cut "to opposite hand," as compared with that on the after pinion, each pair forms virtually a "double helical" set, with the apex of the spirals cut away. These pinion shafts are of nickel steel. The large wheel driven by these pinions is on a shaft forward of, and coupled by usual flange couplings and bolts to, the thrust shaft. This wheel consists of a heavy cast-iron boss and pair of discs, on to which a mild cast-steel hoop is shrunk and pegged. In this hoop the gear teeth are cut. The pinion and wheel-shaft bearings are incorporated in a heavy cast-iron gear case, which gives them suitably rigid support and encloses the gears so that they may be run under jets of oil and kept free from risk of damage either by dirt or by the accidental introduction of any object that might endanger the gearing. The form of the teeth is involute. This form of tooth has one great advantage for machine-cut gearing, namely, that the correct worm to work with an involute worm wheel, being geometrically equivalent to a "rack" has straight sides to its thread. A simply produced, multiple-threaded, hobbing cutter, of "worm" type can therefore be used on a suitable machine to produce automatically the correct tooth form of the pinions and the large wheel.



Figs 4 and 5.—Arrangement of Geared Turbine Machinery, S.S. "Cairnross."

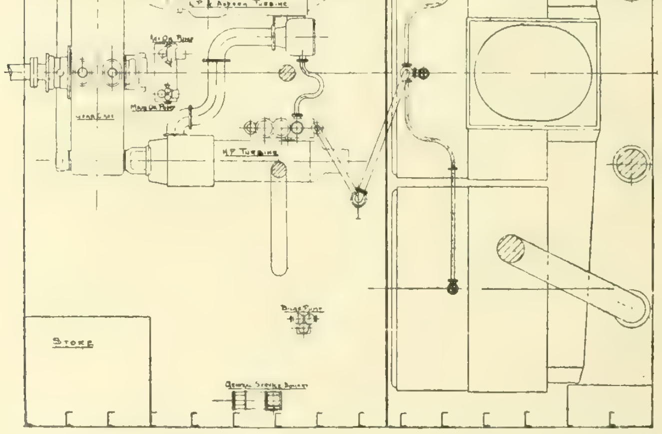


Fig. 6.—Arrangement of Geared Turbine Machinery, S.S. "Cairnross."

The turbines are designed to give their sea power at 1,700 revs. per minute, corresponding to 65 revs. per minute of the propeller. For astern driving, a turbine is embodied in the after end of the port side turbine, the latter being the low-pressure turbine. As usual in such arrangements, the low-pressure and astern turbines exhaust into the same connection, at about the middle of the length of the port turbine casing, so that when one of these is under steam the other runs idly in the vacuum. For compactness, the astern turbine has one impulse stage at its high-pressure end. The power of the astern turbine has not been measured, but appears to be ample. As evidence of this it may be mentioned that whilst the vessel was being worked into the docks at Cardiff a record was taken of one operation, and it was found that in 28 seconds from receipt of the signal on the engine-room telegraph, the propeller was turning at nearly 49 revs. per minute. The handling of the turbines during manœuvring is extremely simple. Beyond the opening and closing of the valves giving steam to the ahead or astern turbines as necessary, nothing is necessary except occasional slight adjustment of the steam supply to such glands as are steam packed against the drawing in of air. At such times the air pumps, the circulating pump, and the oil pump are kept running, and the feed pumps, under control of their float tanks "look after themselves" when in proper order.

The lubrication of the main machinery is effected by oil fed down by gravity from a tank at about the level of the main deck. A thick carbon-filtered pure mineral oil is used,

The same oil is used for the turbine bearings, gear bearings, and gear teeth, the oil being delivered to the latter near the pinions by a series of jets. Oil from all these parts passes by gravity to a closed tank which is dropped into the double bottom, from which it is lifted by a steam-driven pump, passed through a filter, and through a cooler, supplied with water from the main circulating pump up to the gravity tank again. The same oil is thus used over again, about 600 gallons being in circulation.

(*To be continued.*)

THE LAY-OUT, DESIGN, AND EQUIPMENT OF INDUSTRIAL WORKS.

An interesting paper on this subject was read by Mr. A. Home-Morton at a recent meeting of the Liverpool Engineering Society. Industrial works design was, he said, a special branch of applied engineering and involved consideration of every problem which might arise from the conception to the realisation of the scheme. No one was better fitted to study these than the engineer. A sound technical training combined with a keen insight into international industrial movements and the faculty of observation were his basic qualifications. The blunder which was perpetrated on all hands in this country to-day was the creation of industrial works and the birth of industries without adequate time having been spent on their real design. The author divided his subject into six sections: (1) General and financial considerations; (2) labour and labour conditions; (3) general arrangements; (4) generation and transmission of energy; (5) design and consideration of the works structure; and (6) reconstruction.

The stress of competition in modern industry demanded efficiency with economy in every department. Industrial engineers were in consequence frequently called upon to supplement estimates of the capital cost of a projected undertaking with estimates of the working costs, maintenance, and even of profits. These demands in proprietors' interests were, under certain conditions, legitimate and desirable, and the engineer-designer must be able to satisfy the proprietor with such estimates, accurate to within a moderate percentage. Careless estimating ought to be inconsistent with professional honour.

Due consideration of and for the worker was now, he said, being accepted as a sound business policy. There was a tendency towards improved labour conditions and the reduction of physical drudgery by the introduction of aids to labour. A certain school of economics contended that the increase of mechanical appliances tended to lower the standard of excellence and skill in handicraft, and, consequently, the intelligence of the craftsman, but it was equally true that the greater perfection of the results, increased rate of production, and usually greater reward obtained with mechanically-aided labour tended to improve labour conditions, and to uplift, rather than to degrade, the worker. It must be clear that in order to secure not only quantity but quality of output, the interest and skill of the worker and the perfection of equipment must be maintained unimpaired.

A works general arrangement must be considered with reference to the character and quantity of the output, and the limitations and disabilities of the site. Actual works designed to produce the same commodity on sites of varying form were found on examination to have similar essential areas, even although they might differ somewhat in arrangement. This suggested a relationship between floor area and output, which, theoretically, ought to hold, and on investigation would be found to apply even in works which had grown from humble beginnings. Such a ratio of floor area to output would vary with the magnitude of the output, although it would probably hold for average conditions over a considerable range in magnitude.

The first essential to a general arrangement design was the "process diagram," and the second the "routine diagram." The process diagram was simply the enumeration in tabular form, or the graphical presentment, of the several works processes. For example, in paper mills, the several processes were sorting and cutting, dusting, washing, breaking, bleaching, beating, colouring, paper making, drying, sizing, and glazing. In the manufacture of cotton they were bale-opening, mixing, cotton-opening, scutching, carding, drawing, lapping, combing, slubbing, roving, mule and ring spinning, doubling, twisting, winding, gassing, reeling, bundling, tying, pirn winding, warping, and sizing. When to a graphical diagram of a process of manufacture was added a complete schedule of the areas required to house the machines necessary to produce a given output, then a complete "process diagram" was the result.

From the process diagram and the base areas already mentioned, the engineer-designer with an intimate knowledge of the whole process of manufacture, and of the machines necessary to accomplish the process in each particular section, might proceed to prepare the routine diagram, which represented graphically the flow of work in process. In preparing this, works should be so arranged that the material dealt with and manufactured should flow through them in an orderly manner, in one direction, so far as might be, and without waste of time, energy, or material. The routine diagram was probably the most difficult part of works design. It involved the sequential arrangement of the machines within each department, and thereafter the laying out of the departments relative to each other. To carry this out successfully required great skill and care, and probably much tactful discussion with the proprietors, managers, and foremen of the proposed works. From the data available, however, suitable approximate linear dimensions and heights for buildings might be fixed, and thereafter the manipulation of these blocks might proceed until the most satisfactory relative positions of departments were secured. The routine diagram was complete when the several departments were arranged on paper, and the flow of work in progress through the departments was as perfect as possible. The first design was rarely final, for the final plan was usually a combination of the leading features of several draft plans. It could not be too well remembered that the works buildings should accommodate the plant, that the process of manufacture should not require to accommodate itself to the buildings, and that the transmission of power was an integral part of the scheme, and must be considered from that standpoint.

The subject of power generation and transmission in industrial works had been frequently and exhaustively treated in recent years. The mass of information was, however, so technical, so varying, and so conflicting in its conclusions as to be, in a great measure, beyond the grasp of most power users. The first conclusion, and that to which it was difficult to reconcile the partisan mind, was that each system of power generation and transmission had its particular advantages and superior economy, and that maximum economy in works driving in a particular case might be obtained by a combination of two or more systems. The difficulty was usually not so much the selection of the system as the determination of the extent to which it should be utilised. Where the plant was compact and conveniently arranged within a radius of, say, 100ft. or 150ft. from the central power plant, mechanical transmission was most economical, while, with an increased radius, gas or electrical transmission had advantages. The former was the most attractive system from the point of view of thermal efficiency, but it had a more limited application. In small works and factories the most careful thought ought to be given to the works design in order to ensure a compact arrangement and efficient mechanical transmission. The chief advantages of the electrical transmission system were its adaptability and the ease with which it could be extended. Its chief drawback was its cost, a part of which, at least, was due to the refinements which had been introduced into electrical controlling and operating mechanism.

Under the industrial conditions which held to-day and were becoming increasingly stringent, no manufacturer who was building or reconstructing works or mills could afford to neglect the technical skill which was at his disposal quite irrespective of cost. It might be argued that a works manager or proprietor knew most about his business and its needs. But it could be urged quite legitimately that the proprietor's business might be the mining of coal, or the manufacture of iron or steel, ships, chemicals, or textiles. In that sphere he was at his best, but in the design of buildings, the selection of power plant, or even the economical arrangement and correlation of them he was at a disadvantage. Whether this disadvantage was serious or might only involve a permanent tax upon his business, when accepted, must be left to his own judgment. Those industries which held a world-wide reputation in America, in Germany, and in this country had in every instance been either originally designed or reconstructed by experts.

SIX-STROKE CYCLE INTERNAL-COMBUSTION ENGINE.

THE Transactions of the American Society of Mechanical Engineers for April contains the following particulars of a new six-stroke cycle internal-combustion engine, designed by E. Schimanek, and described by him in "Zeits. des Vereines deutscher Ingenieure."

The improvement of the output of internal-combustion engines may be sought along the following lines: (*a*) Improvement of economic efficiency by better fuel utilisation (the gases are subjected to a longer expansion, the volume at the end of expansion is equal to cylinder volume or that at the beginning of compression): has been proved theoretically and practically that, with increasing compression, beyond certain limits the advantages practically stop, and, *e.g.*, in the case of constant-pressure engines, compression above 38 or 40 atmospheres does not improve the efficiency any more. (*b*) Increase of the number of working strokes per unit of time. This can be done in two ways: (1) by increasing the speed of the engine (speed above 200 to 300 revs. per minute does not improve the efficiency any more, while high speed always unfavourably affects the life of the engine); or by (2) the reduction of the number of strokes at which no work is done (double-acting and two-stroke cycle engines; a calculation is given to show how the efficiency of the two types compare with each other). (*c*) Increase of the amount of air handled by the motor per fuel charge (by lowering the temperature of the air, reduction of the amount of products of combustion remaining in the working cylinder and filling up the space thus liberated by clean air, and by increasing the air pressure previous to compression).

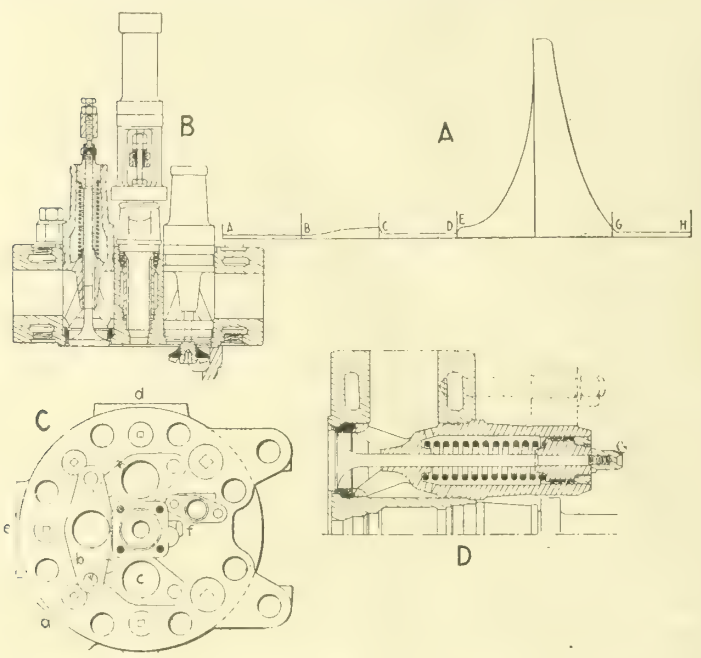


FIG. 1.—SCHIMANEK SIX-STROKE CYCLE INTERNAL-COMBUSTION ENGINE.

The second of these methods is applied in the so-called scavenging engines, as well as to a certain extent in six-stroke cycle engines. In the case of a four-stroke cycle engine, the output may be increased by supplying to the working cylinder compressed air from a special receiver in which the compressed air is replaced by a pump. The pump must then supply the entire air handled, and the dimensions of the working and pump cylinders depend on the desired pressure or improvement in the output; the pump, which works on the two-stroke cycle, must have a cylinder either equal to the working cylinder, if it is single-acting, or of half its volume, if it is double-acting, so that the ratio for the same output between the combined cylinder and pump volume for the improved and ordinary types of four-stroke cycle engines is for two atmospheres pressure in the first case $a = 1$, and in the second $a = 0{\cdot}75$; for 1·5 atmospheres pressure a becomes respectively 1·166 and 0·913. Another way is to take part of the air from outside, and only supplement from the receiver. In this case the working process is as follows: the working cylinder at the first stroke draws in outside air, and at the end of the suction stroke, after the suction opening has been closed, the working cylinder is set into communication with the receiver, so that the air compressed by the pump flows into it and raises the pressure; this is followed by the usual compression, expansion and exhaust. If now the working cylinder takes in as much air from outside as from the receiver, then previous to compression (isothermic compression in the pump and instantaneous free-of-losses passage of air to the working cylinder at the dead centre being assumed) the pressure in the working cylinder is two atmospheres and the output twice as large as in the ordinary four-stroke cycle engine. Since with a single-acting pump the total volume of the working and pump cylinders is $1 + 0{\cdot}5$, the ratio a becomes $\frac{1{\cdot}5}{2} = 0{\cdot}75$; with a double-acting pump it is $a = \frac{1 + 0{\cdot}25}{2} = 0{\cdot}62$.

The thermal efficiency of such an engine is somewhat lower than that of an ordinary four-cycle engine, and the more so the smaller the size of the receiver because in the overflow of air, apart from acceleration and throttling losses, there are losses due to the flow of air from the receiver where it is at a high pressure, to the cylinder where a lower pressure prevails. But the efficiency of a four-stroke cycle may also be improved without introducing a separate air pump, by applying a special process invented by the author. The essential part of this new process consists in making several suction strokes before each compression or expansion stroke. The air taken in before the last suction stroke is stored in a receiver up to the last suction stroke, when it is conveyed to the working cylinder and there forms part of the explosive charge. This cycle may be of six or more strokes. In the six-stroke cycle shown in Fig. 1 A the sequence is as follows: stroke 1: suction of outside air, A—B; stroke 2: compressed air driven into the receiver, B—C; stroke 3: suction of outside air, C—D; between the third and fourth strokes the air flows over from the receiver into the working cylinder, where the pressure rises to about two atmospheres, D—E; stroke 4: compression of the charge, E—F; stroke 5: combustion and expansion, F—G; stroke 6: exhaust, G—H. With this process in six strokes twice as much air is handled as in a four-cycle engine in four strokes, and, for the same number of revolutions, the output is 1·33 times as great as in the latter type; not counting losses connected with the overflow of air, the same cylinder volume in the six-stroke cycle gives about 33 per cent. more output than in the four-stroke.

In actual operation, however, this is not quite so. The conditions are the same as in a four-stroke cycle engine only during the first suction stroke, while previous to the second and following strokes the pressure in the compression space of the cylinder is that of the receiver, and the volumetric efficiency is therefore affected by the expansion of the air from the receiver pressure to the atmospheric. At the second and following (in engines of cycles higher than the six-stroke) suction strokes the volumetric efficiency can be good only when the compression space is not too large, and the application of this principle is therefore limited to engines with a high compression pressure, that is, to constant-pressure engines.

As regards the ignition of the fuel only small amounts of heat can escape through the receiver walls, owing to the comparatively low temperature of the stored-up air and its low conductivity; the fall in temperature due to this loss of heat is further compensated for by the rise of temperature due to throttling. The final temperature does not therefore substantially differ from that of four-stroke cycle engines using similar pressures, and the final pressure need not exceed 60 atmospheres, as in the four-stroke cycle engine. Actually, however, only about 50 atmospheres are used, which makes a larger compression space necessary, and somewhat reduces the thermal efficiency of the engine. As regards losses of heat to the cooling water, in the four-stroke cycle the cooling does no useful work during the suction and exhaust strokes, and affects the compression stroke but little. It affects harmfully the utilisation of the fuel heat content only during the combustion and expansion strokes. In the six stroke cycle there are five strokes during which the cooling water does no harm, and therefore for the same number of revolutions per minute the loss to the cooling water is less in the case of the six-stroke cycle engine than in the four stroke cycle. The Schimanek engine working on the six-stroke cycle is shown in Fig. 1, B and C, and the overflow valve permitting the air to flow from the receiver into the cylinder between the third and fourth stroke, as explained above, is shown at Fig. 1, D. The useful output of the new engine (about 40 h.p.) was found to be 20 to 25 per cent. in excess of that of a four stroke cycle engine of similar dimensions. No data is given as to the first cost of the new engine.

THE DEVELOPMENT OF THE WESTINGHOUSE TURBINE.*

BY H. T. HERR.

In the early experiments made at The Westinghouse Machine Company, under the direction of Mr. George Westinghouse, a system of turbine elements was developed by Mr. Westinghouse consisting of a combination impulse turbine for the high-pressure stages, and reaction or Parsons elements for the low-pressure portions of the turbine, the object of the combination being to secure, without sacrifice in economy, a more stable mechanical construction by shortening the machine and dispensing with the necessity for three balancing pistons, as obtained in the Parsons design originally exploited. This combination was particularly desirable at the time of its introduction by Mr. Westinghouse on account of the relatively low powers then required in turbo-generator work, although very successful machines have been in operation here and abroad of the straight Parsons design, which lends itself admirably to certain operating conditions.

The ability of the Curtis element to extract at a given blade speed considerable energy in the high-pressure stage of the turbine with good efficiency resulted in its adoption by Mr. Westinghouse for the high-pressure portion of his machine, by which 20 per cent. to 50 per cent. of the energy of the total expansion is extracted, leaving to the Parsons blading in the low-pressure portions of the turbine the balance of the work to be done with the most efficient turbine elements.

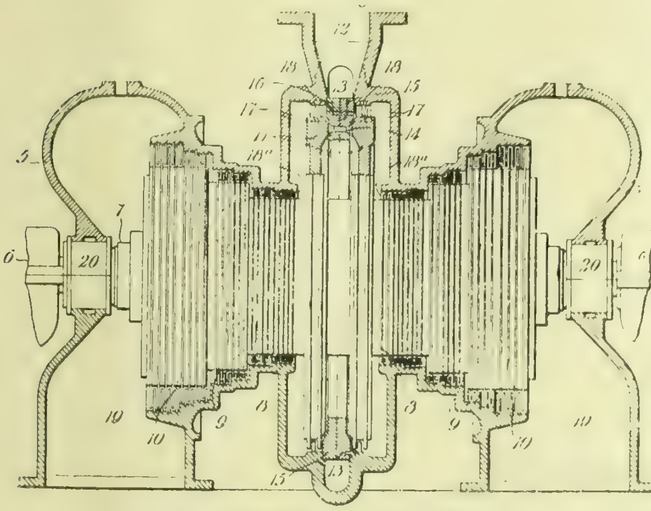


FIG. 1.—WESTINGHOUSE STEAM TURBINE.

The impulse wheel in this construction replaced a large number of rows of Parsons blading with equivalent economy, because in the smaller powers it was necessary in the straight Parsons machine, on account of total peripheral admission, to make the blade speeds relatively low in order that their height might be as large as practicable, to reduce the proportion of leakage by the end of the blades due to the necessary blade clearances. As this development proceeded, the demand for higher capacity generators increased, and to meet this demand it was necessary to materially enlarge the low pressure portions of the turbine, which, in some instances, required a dividing of the Parsons blading into two sections, commonly known as the double-flow low-pressure expansion.

In 1903 Mr. Westinghouse filed his application for patent on the combination impulse reaction double-flow turbine illustrated in Fig. 1. With this construction the balancing pistons required by the straight Parsons machine were entirely dispensed with, and while for double-flow construction twice the number of blades were required as for similar conditions with single-flow, yet the application of the impulse wheel to the high-pressure stages made possible, in a great many instances, the proper mechanical design, on account of the considerable shortening of the turbine due to the introduction of the impulse wheel, thus allowing a length of spindle and cylinder of proper mechanical stability.

As this development progressed it was found advisable, on the score of efficiency, to resort to the Westinghouse single double-flow construction. This differs from the straight double-flow principle in utilising a single Curtis impulse wheel with two rows of revolving blades, followed by a single barrel of reaction blades, after which half of the steam is allowed to pass through the drum around a balancing piston (for the single barrel of Parsons blades) to half of a double-flow expansion of reaction blading, and thence into a double exhaust opening at either end of the turbine, as illustrated in Fig. 2. The intermediate reaction blading was thus allowed to be proportioned with blades of twice the length and half the number as would have obtained had the entire reaction blading been made double-flow.

Since the efficiency of reaction blading is a function of its length, assuming the blade clearances the same, it is apparent

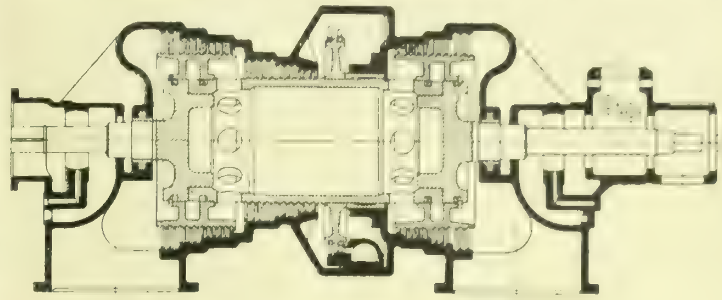


FIG. 2. SEMI-DOUBLE FLOW TURBINE.

that this single double-flow construction is adaptable to turbine units of moderately high capacity, depending on the rotative speed. This construction is now used in turbo-generator units for alternating current from 3,000 kw. to 10,000 kw. at speeds of 1,500 to 1,800 revs. per minute.

In the development of the higher-powered turbo-generator units (above, say, 10,000 kw. at 1,500 or 1,800 revs.), owing to the large volume of steam handled, the best proportioning results by making the reaction blading double-flow with a Curtis impulse wheel carrying two rows of blades and utilised in the high-pressure portion of the turbine. Here the reaction blading may be operated at sufficiently high blade speeds to materially reduce the number of rows and make a comparatively short machine, notwithstanding the fact that twice the number of rows of blades are required on account of the double-flow principle than would be necessary if single-flow elements were resorted to.

These various constructions have, as will be seen, their particular field of usefulness, depending on the operating conditions and the speeds for which the turbines are designed. The great importance in the turbine art of this combination

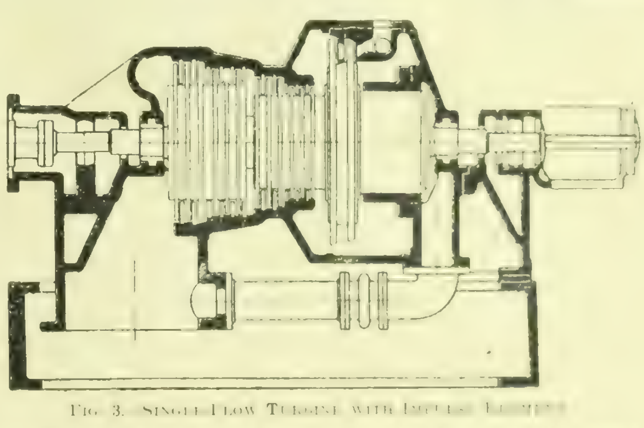


FIG. 3. SINGLE-FLOW TURBINE WITH [illegible].

turbine has been realised principally in the past five years in the field of electric power generation, because it gives great flexibility and permits the use of high pressures and high superheats without the deleterious effect these operating conditions might impose with the more difficult mechanical construction of long cylinders and spindles subjected to wide ranges of pressure and temperature. The effect of the combination machine may perhaps better be understood by taking the following practical example.

Steam is to be delivered to the turbine at 200 lbs. pressure gauge and 150° superheat, and is to be expanded to 28 in. vacuum. Its temperature, therefore, entering the turbine would be 538° Fah. With the Westinghouse turbine the

* From a paper entitled "Recent Developments in Steam Turbines," read before the Franklin Institute.

steam would enter the nozzle chamber and be expanded through the nozzles to 78·8lbs. absolute with the impulse wheel operating at a blade speed of 500ft. per second. Its temperature and pressure would therefore be in the impulse chamber 328° Fah. and 78·8lbs. absolute respectively, which are sufficiently low to give an entirely satisfactory mechanical construction of the low-pressure end. The construction of such a turbine is shown in Fig. 3. If the steam expansion were to take place in the equivalent Parsons turbine, the construction would be as illustrated in Fig. 4. A very material shortening of the spindle is secured by the replacement in the Parsons turbine of the high-pressure portions, correspond-

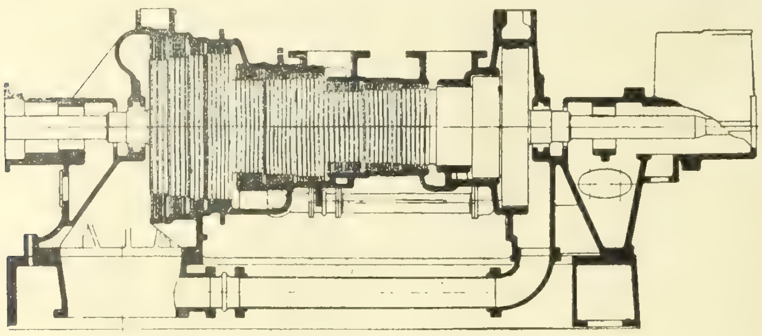


FIG. 4.—SINGLE PARSONS TYPE TURBINE.

ing to the equivalent expansion as would take place in the nozzles of the impulse wheel, and with the same efficiency, because the impulse wheel replaces the most inefficient portion of the Parsons turbine.

In the matter of economies at fractional loads, the substitution of the impulse element for its equivalent Parsons blading in the high-pressure portion of the turbine allows greater efficiency, because, with the impulse construction, nozzle control can be resorted to, thus converting into useful work a portion of the energy of the steam which would be lost in a straight Parsons turbine due to throttling. In other words, with the nozzle control construction the impulse wheel becomes an efficient reducing valve when the turbine is operated at fractional loads.

While this advantage may not in a good many instances be very material, and may not warrant the ordinary complications incident to nozzle control, yet in principle it is proper to utilise it for the same flexibility with greater efficiency, and it is only necessary to design a mechanical nozzle control apparatus whose complication is less than the advantages gained by the economies in its use in order to make this arrangement a most satisfactory and desirable one.

The great flexibility of reaction blading over wide variations of pressure distribution, and its adaptability especially to handling large volumes of steam efficiently, make its application particularly desirable in the low-pressure portions of

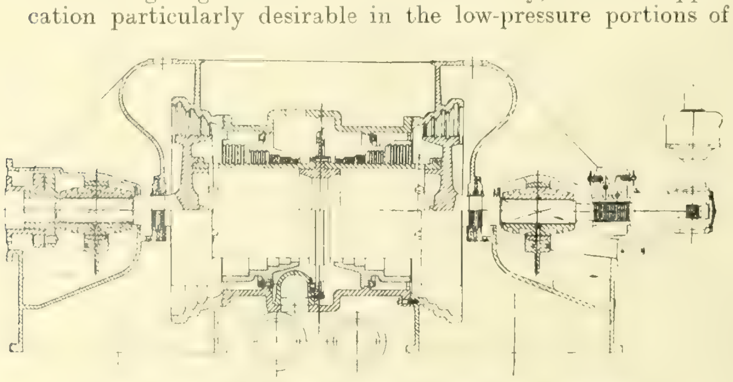


FIG. 5.—25,000 K.W. STEAM TURBINE, 1,500 R.P.M., CONDENSING.

turbines. There are, however, operating conditions now arising in power plant development which make more suitable the adoption of reaction blading for the high-pressure portion of turbines than has heretofore obtained. This condition has been particularly brought about by the development of the alternating-current generator to operate at high speeds, generating large power. This can probably best be illustrated by some recent designs prepared by the Westinghouse Machine Company for generator units of 15,000 kw., 20,000 kw., 25,000 kw., and 30,000 kw. capacity. In such units it is of the utmost importance to secure the very maximum of economy in steam consumption, because the output of the units is so enormous that a small loss in efficiency means a very large increase in the cost of operation.

With the development of the electrical art, alternating-current generators of 5,000 kw. can be built at 3,600 revs. per minute, from 5,000 kw. to 25,000 kw. at 1,800 revs. per minute, and from 5,000 kw. to 30,000 kw. at 1,500 revs. per minute, the different speeds corresponding to 60 and 25 cycles, as used in this country. Likewise, the turbine is susceptible of generating in one unit the necessary power to drive the above generators at these particular speeds. Some two years ago designs were proposed by the Westinghouse Machine Company for a 25,000 kw. unit to operate a 25-cycle generator with operating conditions of 200lbs. steam pressure, 200° superheat, and 29·2in. vacuum. Four solutions of this condition were worked out, as follows: (1) A Westinghouse double-flow turbine at 1,500 revs. per minute, direct connected to a 25-cycle generator of 25,000 kw. maximum capacity, as illustrated in Fig. 5. (2) A single double-flow Westinghouse turbine running at 750 revs., direct connected to a 25,000 kw. generator, as illustrated in Fig. 6. (3) A tandem compound Westinghouse-Parsons turbine at 750 revs. per minute, the high-pressure portion being single-flow and the low-pressure portion being double-flow, direct connected to a 25,000 kw. generator, as illustrated in Fig. 7. It is evident that this machine could be arranged cross-compound with two generators of 12,500 kw. each. (4) A cross-compound Westinghouse-Parsons turbine with the high-pressure portion running at 1,500 revs. (Fig. 8), direct connected to a 12,500 kw. generator, and a double-flow, low-pressure, Westinghouse-Parsons turbine running at 750 revs. (Fig. 9), direct connected to a 12,500 kw. generator.

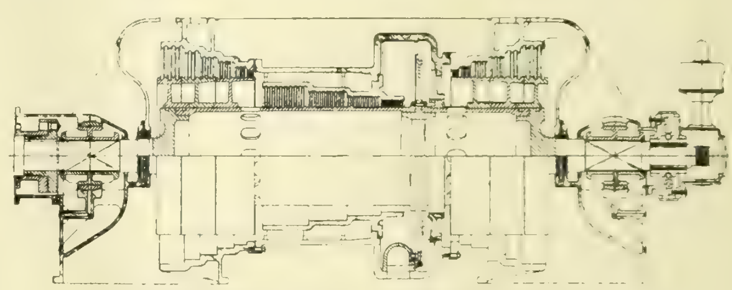


FIG. 6.—25,000 K.W. STEAM TURBINE, 750 R.P.M., CONDENSING.

All of these arrangements would give very excellent economy, and the choice of the unit would depend primarily on the two factors of first cost and economy, assuming that in each case the reliability for continuous operation is the same. A close study of the four arrangements indicates that the Westinghouse double-flow turbine at 1,500 revs. per minute, direct connected to a single generator (Fig. 5), is the cheapest construction. The large areas required in the low-pressure stages of this turbine make high velocity and long length of blade essential, with the necessity of careful designing to properly take care of the stresses due to centrifugal force in the low-pressure end. The most economical combination of the four is the cross-compound Westinghouse reaction turbine with the high-pressure portion running at 1,500 revs. and the low-pressure portion at 750 revs. With this arrangement the highest efficiency is obtained, because with the large volumes of steam required to develop the high power and the ability to combine the unit into high and low-pressure cylinders running at 1,500 and 750 revs. per minute, gives the condition for best blading proportions throughout the turbine without departing from standards of practice already established. This machine would be very remarkable for its high efficiency, which it is believed could not be reproduced with any other known form of turbine. The construction, however, is considerably heavier than the single unit commented upon above, and would be more costly to construct and install.

In such a case as the one cited there is little doubt that the cross-compound Parsons machine will give the maximum efficiency. At powers and speeds attainable with single alternating-current units of, say, below 15,000 kw. capacity the Westinghouse double-flow turbine between 10,000 kw. and 15,000 kw. will be nearly, if not equal, to the cross-compound straight reaction turbine under like operating conditions,

and any difference in efficiency would probably be offset by the difference in first cost in favour of the Westinghouse double-flow machine. Between 10,000 kw. and 4,000 kw. capacity the Westinghouse single double-flow machine would undoubtedly be the proper construction, taking into consideration the first cost and efficiency.

The demand for turbo-generator machines is greatest in kilowatt output between the sizes of from 4,000 kw. to 15,000 kw. maximum rated capacity, within which range the Westinghouse single double-flow and Westinghouse double-flow machines most admirably meet the commercial conditions both with respect to cost and efficiency. Below 4,000 kw. capacity the Westinghouse turbine consisting of (1) an

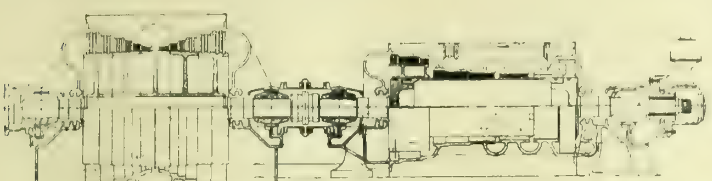


Fig. 7.—5,000 K.W. Steam Turbine, 200lbs. Boiler Pressure, 750 r.p.m., Condensing.

impulse wheel followed by single-flow reaction blading, illustrated in Fig. 3; (2) an impulse wheel followed by single double-flow reaction blading (Fig. 1); (3) an impulse wheel followed by double-flow reaction blading (Fig. 5); and (4) a single-flow Westinghouse reaction turbine (Fig. 4), represent the various choice of machines best suited for operating conditions (*a*) dependent on the initial pressure and superheat, (*b*) on the number of revolutions at which the generator or other driven machine rotates, and (*c*) on the capacity.

Thus with a speed of 3,600 revs. per minute, driving a 60-cycle generator at, say, 3,000 kw., the turbine design would follow the combination impulse double-flow reaction machine for best efficiency and lowest cost (Fig. 5). If, however, the generator to be driven was 25-cycle, with an allowable maximum speed of 1,500 revs. per minute and a capacity of 3,000 kw., the choice would lie between a design of a straight single-flow reaction turbine and a combination impulse single-flow reaction turbine, the former being used for moderate degrees of superheat and initial pressure, and the latter for high superheat and high pressure.

In general, however, the application of the Westinghouse turbine, consisting of an impulse element for the high-pressure portion and reaction blading for the low-pressure portion, is admirably adapted for complete expansion turbines over wide ranges of power and speed, and since the introduction of this type in 1903, following the initial designs by Mr. Westinghouse, a large proportion of the firms building steam turbines have utilised this construction, either with Parsons or Rateau blading, following the Curtis impulse element or elements in the high-pressure end.

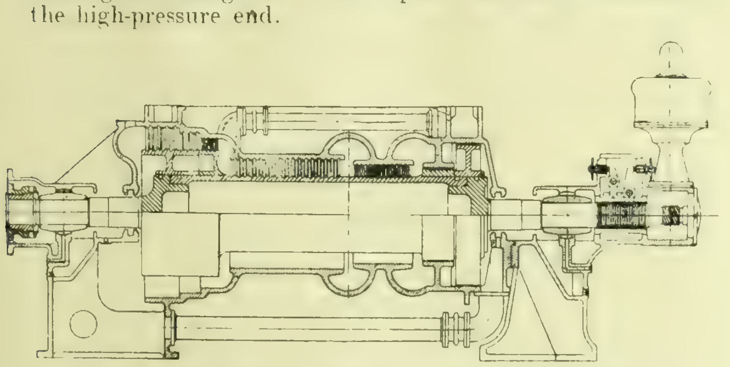


Fig. 8. 25,000 K.W. Steam Turbine, High Pressure Element. 200lbs. Boiler Pressure, 1,500 r.p.m.

The advantages of the Westinghouse type are: (1) the ability to shorten the machine by the introduction, in the high-pressure stages, of an impulse wheel of the Curtis type without material loss in efficiency where the powers and speeds are relatively low; (2) the reduction of pressure and temperature within the turbine cylinder by expanding the steam initially in fixed nozzles; (3) the elimination of two or more balancing pistons as obtain in the straight Parsons machine, consequently reducing the small, balancing piston clearance, and leakage of steam incidental to their introduction; (4) the retention of the most efficient turbine elements in that portion of the machine where they can be most effectively employed for efficiency; (5) the ability to secure higher economies at fractional loads by the introduction of nozzle control on the initial impulse element; and (6) the retention of the drum construction for rigidity of spindle and low cost of manufacture, referring particularly to the reaction blading.

The disadvantages of the Westinghouse construction are: (1) for extremely high powers, say, above 15,000 kw. capacity, the impulse wheel is less efficient than its equivalent Parsons blading, depending, however, on blading proportions. (2) for capacities of 300 kw. at 3,600 revs. per minute, and 750 kw. at 1,500 revs. per minute, the construction, while applicable at these powers and speeds, becomes as expensive with the same efficiency as turbines of other designs.

For the smaller powers, therefore, the Westinghouse Company developed some three years ago impulse turbines of the re-entry type, which are adaptable down to units of 1 kw. capacity, having the advantage of one revolving row of blades, with which it is possible to obtain (*a*) a sub-divided impulse

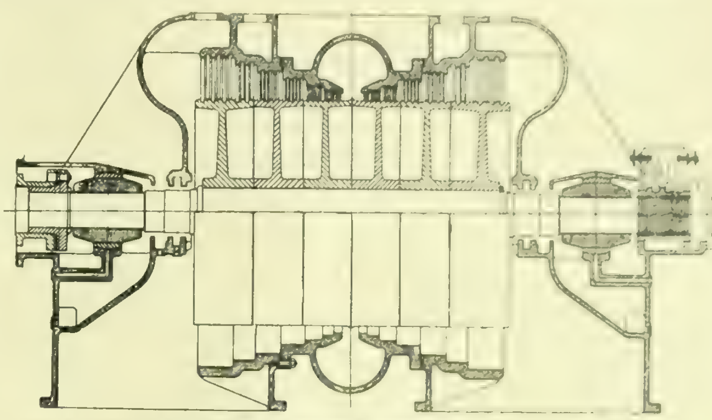


Fig. 9.—25,000 K.W. Steam Turbine, Cross-compound Condensing. High Pressure, 1,500 r.p.m.; Low Pressure 750 r.p.m. Section through Low Pressure Cylinder.

turbine with one reversal, equivalent to a Curtis turbine with two revolving rows of blades, used for medium-pressure drops; (*b*) a sub-divided impulse turbine with two reversals, equivalent to two Curtis elements with four revolving rows of blades; and (*c*) sub-divided impulse elements with one or two reversals followed by one or more Rateau stages, or a series of Rateau stages without Curtis elements. This construction has the advantage of the simplicity of the De Laval turbine operating efficiently at such rotative speeds as are commercially required for the purposes of direct connection to generators, pumps, blowers, and other machines which require relatively good efficiency with relatively low speed of rotation.

Institution of Electrical Engineers: Glasgow Section.—In their report for the past year the committee of the Scottish Local Section of the Institution of Electrical Engineers state that the membership is 390. During the year the articles of association were revised, and the committee state that it is a matter for congratulation that, notwithstanding the increase in the amount of the annual subscriptions, the numerical strength of the institution as a whole, and that of the Scottish Section, shows a substantial increase. Admission to the institution as graduate or associate member, or transfer from the grade of graduate to that of associate member, will in the future be by examination, and this, it is believed, will result in raising the status of the institution and its membership. Office-bearers for next session will be as follow: Chairman, Mr. J. A. Robertson; vice-chairmen, Messrs. James Lowson and T. Blackwood Murray; past chairmen (ex-officio members of committee), Messrs. Sam Mavor, Frank A. Newington, and William M'Whirter; chairman of students' section, Mr. Archibald Page; ordinary members of committee, Messrs. David A. Starr, J. K. Stothert, J. F. Nielson, Wilfrid L. Spence, M. B. Field, J. H. Bunting, J. S. Nicholson, E. T. Goslin, and George Stevenson; hon. secretary and treasurer, Mr. James E. Sayers; assistant honorary secretary, Mr. William F. Mitchell; hon. secretary of students' section, Mr. James W. Mowat.

GRATE ARRANGEMENTS FOR GAS PRODUCERS.

Two arrangements of grates for gas producers have recently been patented by Messrs. Crossley Bros., Ltd., Openshaw, Manchester, in conjunction with Mr. Frank Fielden. The

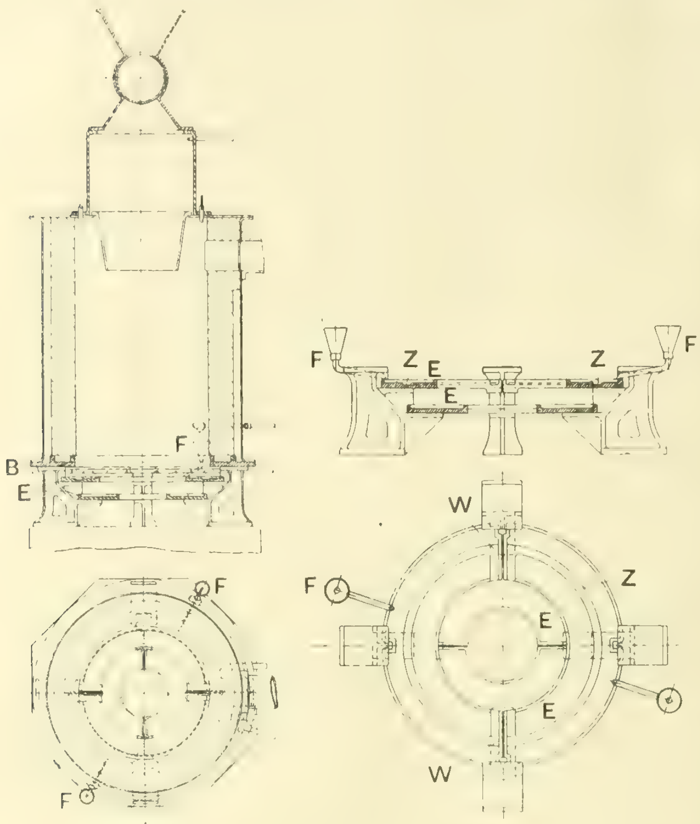


FIG. 1. FIG. 2.
GRATE ARRANGEMENTS FOR GAS PRODUCERS.

one shown in Figs. 1 and 2 is applicable to open-hearth suction producers and comprises a stepped firegrate, circular in form, and open to the atmosphere all round. The generator consists of a mild steel case on the base of which a cast-iron ring B of channel section is arranged to carry the firebrick lining. This casting B is supported by a number of feet which also act as supports for the stepped firegrate E. This firegrate is composed of a series of circular plates arranged in steps and so shaped on their upper surfaces as to be suitable for the vaporisation of water run directly on to them from a supply pipe and funnel F. The circular plates of the firegrate are of such a width and are so arranged relatively to each other as to prevent any fuel or ash from falling off the outer edges of the plates. The section of the plates may be in the form of a channel with overflows in the channel at opposite sides or ends of the grate for the purpose of taking any superfluous water on to the next lower step. The outer edges of the stepped grate are flanged for the purpose of retaining a thin film of water for vaporisation purposes. As shown in the plan view, Fig. 2, a channel Z is formed about mid-width of the upper firegrate E with overflows W at opposite sides or ends for any surplus water.

The arrangement shown in Fig. 3 has been designed primarily for the consumption of pithead slack or waste and similar fuel with a very high ash content, and consists in the provision of an automatic ash ejector comprising a reciprocating table placed below the grate, to which a variable speed is given by gearing to push off the ash from the generator and deliver it into the ashpit. In the base of the generator a firegrate A, of the inverted cone type, is so fixed that its bottom edge stands some distance above the base support B of the fuel bed. This base support is relatively to the cross-section of the grate sufficiently large to prevent any ash from rolling away. The ash ejector proper consists of a metal table C which is caused to reciprocate at a regular but adjustable speed to suit the particular quantity of ash contained in the fuel to be gasified. This reciprocating table C is shown driven by means of a train of gearing D working in mesh with a rack E on the underside of the table. The support for the inverted conical grate is of novel construction, that half F of the support which is more subject to the thrust set up by the reciprocating table C consists of a semi-circular or crescent-shaped casting carrying in its upper edge a slot for the grate bars and being tapered at its lower edge to assist in shearing any large masses of clinker which may accumulate during the working of the plant. This half support is itself carried and strengthened by stiff rigid brackets G bolted to the side of the gas generator, the outer surface of which is reinforced by tee or angle irons. The other half H of the conical grate support is arranged with respect to the upper edge as a support for the grate bars and its lower edge is extended downwards to the reciprocating table C to act as a scraper, its function being to prevent any ash being withdrawn by the table on its return or backward motion. An auxiliary scraper J is fixed by angle irons some distance behind the firegrate support and scraper for the purpose of preventing any ash which falls from the grate bars on the same side of the producer from passing backwards with the table C. This table carries side plates which form supports for flanged wheels running on rails. On two sides of the base the foundation is cut away in the shape of an inclined plane N to conduct any ash which rolls off the side of the base into the lute, from whence it is removed by hand or by an ash hoist. The bottom of the generator case is extended on one side to form a steam and air-tight box P which effectually guards the table during its backward motion.

In operation fuel is fed into the producer in the ordinary

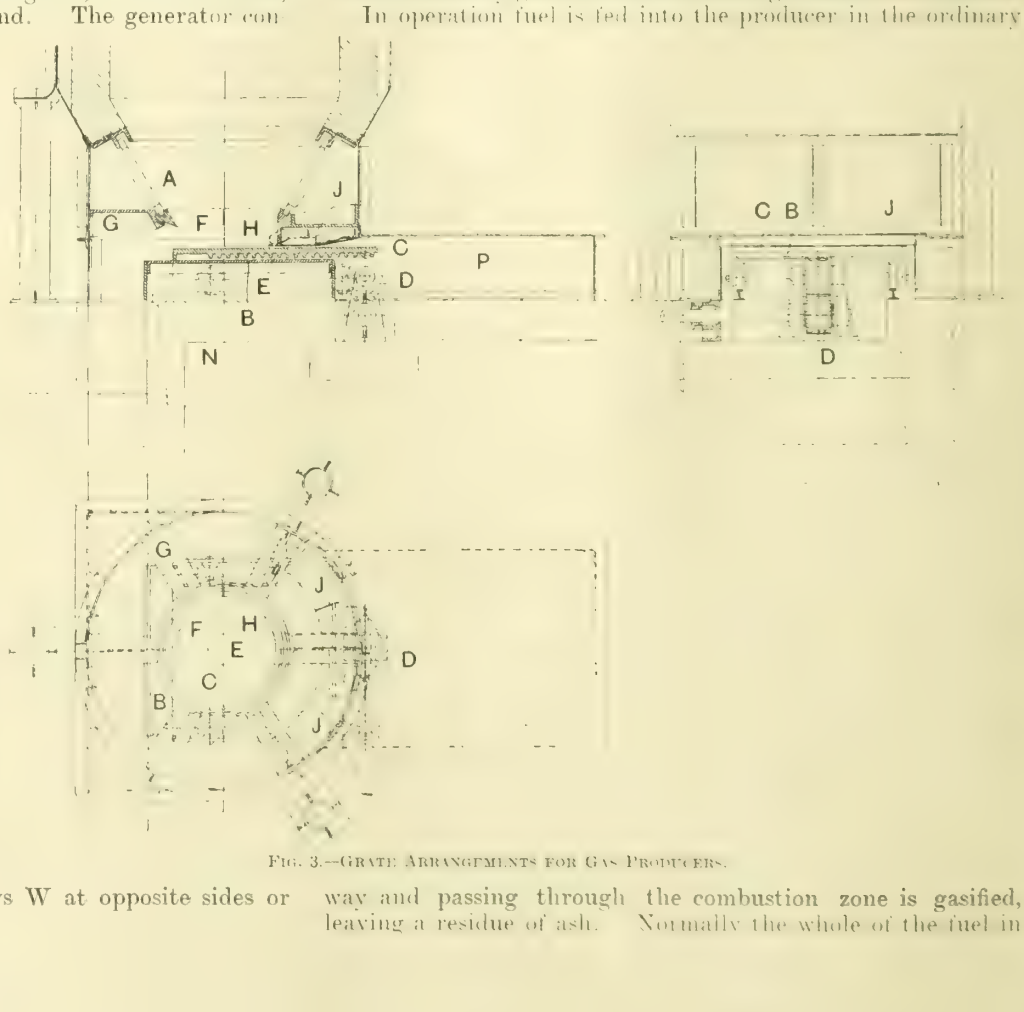


FIG. 3.—GRATE ARRANGEMENTS FOR GAS PRODUCERS.

way and passing through the combustion zone is gasified, leaving a residue of ash. Normally the whole of the fuel in

the generator is supported by a bed of ash resting on the base B. Since it is necessary to remove the ash periodically at a regular and consistent rate, according to the quantity of ash contained in the fuel, the reciprocating table C is made to pass along the top of the base B, exerting a pushing motion on the ash lying immediately in its path. This ash is pushed along to the edge of the base B and falls down into the lute. On the return or backward motion of the reciprocating table C the space equal to its depth is immediately filled by more ash falling down from above the scrapers H and J effectually preventing any ash from being drawn with the table. The speed of the table can be varied by means of change wheels or equivalents to suit varying quantities of ash contained in the fuel.

THE INSTITUTION OF ELECTRICAL ENGINEERS: EXAMINATIONS.

1. *General.*—On and after June 1st, 1913, candidates for election into or transfer to the class of Associate Members, except as provided in the third paragraph of this clause and in Clause 9, will be required to pass the Associate Membership examination of the Institution. The passing of the examination will not of itself secure admission to Associate Membership. Candidates must also satisfy the requirements of the Articles of Association (Art. 13). In lieu of examination, candidates will be allowed to present a thesis, paper, or other contribution to electrical knowledge, but they will be liable to be examined orally thereon.

2. *Dates and Places.*—The examinations will be held in London twice annually on two days (Friday and Saturday) about the end of April and end of October. Examinations may also be held at the discretion of the Council in other centres, if the number of local entries warrants such arrangements.

3. *Persons Eligible for Examination.*—Applications to enter for the examination will be received only from: (*a*) Students or Graduates of the Institution; (*b*) Candidates who have lodged with the Secretary of the Institution a duly completed Proposal Form for their election into or transfer to the class of Associate Members, and who have been informed by the Council that they must pass the examination, or either part of it, as a condition of election or transfer; (*c*) Candidates who, not having attained the age for admission to the class of Associate Members, shall have given an undertaking on a form approved by the Council to make application for admission as soon as they are duly qualified.

4. *Latest Date for Entry.*—Applications to enter for the examination must be made on the prescribed Entry Form, which must reach the Secretary not later than March 1st for the April examination, and not later than September 1st for the October examination. The Entry Form must be accompanied by the examination fee. Candidates will be informed of the place of examination about March 15th and September 15th respectively.

5. *Examination Fee.*—The examination fee will be: (*a*) For the first entry, £2. 2s.*; (*b*) For any subsequent entry, £1. 1s. Fees will not be returned. Any candidate who withdraws his application, or does not attend the examination, or fails, will be required to pay the fee for a subsequent entry with each further application to be examined.

6. *Provision of Drawing Instruments, Mathematical Tables, &c.*—(*a*) Candidates must bring with them ordinary drawing instruments, squares, and scales. Candidates may also bring slide-rules. (*b*) Mathematical tables (Bottomley's and Dale's), and such other books of reference as may be needed, will be provided in the examination rooms for the use of candidates. (*c*) No appliances other than those specified in (*a*) above, and no books or papers, may be brought by candidates into the examination rooms.

7. *Subjects of Examination, and Time Table.*—The subjects and order of the examination will be as follows:—

Day	Hours	Number of Papers	Subjects
			PART I.
Friday.	10 a.m. to 1 p.m.	1	English Essay, or Translation into English of Passages in *one* of the following Languages, to be selected by the candidate: French, German, Italian, or Spanish.
	2-30 p.m. to 5-30 p.m.	1	Applied Mechanics, and *either* General and Elementary Physics *or* Chemistry.
			PART 2.
Saturday	10 a.m. to 1 p.m.	1	Two papers on *one* of the following subjects, to be selected by the candidate:— (*a*) Electricity Supply. *or* (*b*) Electric Lighting and Power *or* (*c*) Electric Traction. *or* (*d*) Telegraphy. *or* (*e*) Telephony. *or* (*f*) Application of Electricity to Mines. *or* (*g*) Electro-Chemistry and Electro-Metallurgy. *or* (*h*) Manufacture of Electric Machinery including Works Management. *or* (*i*) Design of Electric Machinery and Apparatus.
	2-30 p.m. to 5 30 p.m.	1	

The papers in Part II. will include optional questions on Administrative and Economic Matters.

Candidates must attend in the examination rooms five minutes before the time fixed for the examination. No detailed syllabus of the subjects of examination will be published.

8. *Notification of Results.*—(*a*) A list of the names of successful candidates, in alphabetical order, will be sent to each candidate about one month after the examination. (*b*) The Secretary cannot undertake, otherwise than as stated above, to inform candidates of the results, but he will be prepared to answer written enquiries from unsuccessful candidates as to the papers in which they have failed. Information will not be given as to marks gained or marks required for a pass, or as to detailed particulars of the subjects of examination, nor will certificates be given on the results of the examinations.

9. *Exemptions.*—Any of the following qualifications will exempt a candidate from the whole of the examination: (*a*) Any Engineering Degree of any University in the United Kingdom or in the British Dominions over Seas. (*b*) Whitworth Scholarships. (*c*) The Diplomas or Certificates in Electrical Engineering (as indicated between brackets) granted by the following bodies: The City and Guilds Engineering College (Diploma); The City and Guilds of London Institute (Honours Grade); Faraday House (Diploma); The Finsbury Technical College (Day Course Certificate); King's College, London (Certificate or Diploma); University College, London (Diploma); Heriot-Watt College, Edinburgh (Diploma); The Royal Technical College, Glasgow (Diploma); The Municipal School of Technology, Manchester (Certificate of Technology); Armstrong College, Newcastle-upon-Tyne (Diploma).

Candidates who have obtained a Science Degree from any University in the United Kingdom or the British Dominions will be exempted from Part I. of the examination.

The Council will consider on its merits any other Engineering Degree, Diploma, or Certificate of equivalent standing to those enumerated above which may have been obtained by a candidate from any University or College in the United Kingdom or Abroad.

* In the case of students who have paid not less than three annual subscriptions, the fee for the first entry will be £1. 1s.

Winding Accident at a Colliery.—An accident occurred on the 11th inst. at one of Messrs. Lockers Merthyr Collieries, at Mardy, Glamorgan. Fortunately, the accident was not attended with fatal results, but ten men were more or less seriously injured. A cage containing workmen was being lowered to the bottom, when something went wrong with the winding gear, and the cage was precipitated to the bottom of the shaft. The men in the cage were thrown out and injured, while three men in the up-going cage had narrow escapes.

SELF-SYNCHRONISING MACHINES.*

BY DR. E. ROSENBERG.

Synchronous motors have two advantages over induction motors: (1) They do not require magnetising current from the line; (2) they can be designed, and practically *must* be designed, with a bigger air gap than induction motors.

Their peculiarity of running at an absolutely fixed speed for a given frequency is only in a few cases a real advantage, and more often a serious drawback. The necessity of continuous-current excitation, and of the proper adjustment of same, complicates the machine, and however much the starting apparatus may have been improved, it is certainly more complicated than that of a slip-ring or squirrel-cage motor.

The synchronous motor should, therefore, only be installed where it gives distinct advantages, and only after careful consideration of the conditions. It is useless to improve the power factor of one, say 30 h.p., motor, which only represents a fraction of 1 per cent. of the station load, and which cannot materially affect the power factor of the system whether it runs at unity, leading, or lagging power factor. Of course, it

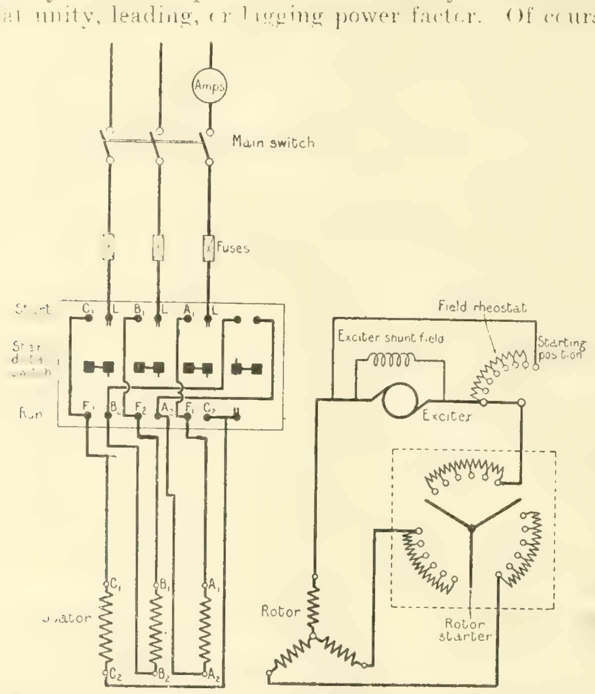


Fig. 1. Diagram of Connections for a Self-starting Synchronous Motor with Distributed Rotor Winding arranged in Three Phases.

would improve the system if all small motors could be made to run at unity power factor, but it is quite wrong to install as a general proposition a most costly machine, and to saddle every workman who starts a lathe or a pump with the obligation of looking after an exciter rheostat and a power-factor meter. It is far cheaper from the point of view of general economy to make the machines in the power station and the cables big enough to carry the magnetising current in addition to the watt current, and to let the power factor look after itself. If, however, opportunity arises of replacing large motors of bad power factor by synchronous motors, then it may be a decided gain and far outweigh the additional complication.

Synchronous machines running over-excited without doing mechanical work have sometimes been used, and have more often been proposed, as "synchronous condensers," to take leading instead of lagging current from the line, and so to compensate for lagging currents produced by other apparatus. A much superior and more efficient method of using the synchronous motor is to make it do some useful work in addition to its beautifying function of improving the power factor. Suppose, for instance, we had a load of 1,000 kw. at 0·707 power factor, *i.e.*, a watt load of 1,000 kw. and a wattless current corresponding to 1,000 k.v.a. If we want to improve the power factor to 0·8 (1,250 k.v.a. at 0·8 power factor, or a watt load of 1,000 kw. and a wattless component of 750 k.v.a.), we have to install a synchronous condenser able to give 250 k.v.a. at a power factor of zero. Such a machine must be much more liberally proportioned in its magnetic system than an ordinary 250 k.v.a. machine, and it will have losses amounting approximately to 25 kw. The addition of the synchronous condenser involves therefore a loss of fully 2½ per cent. of the total output of 1,000 kw., and it is not often that this 2½ per cent. can be fully recovered by the reduced losses in the cables and in the generator due to the reduction of the current. If, on the other hand, we could replace an existing induction motor of 250 kw. input, 0·707 power-factor, by a synchronous motor of 250 kw. running at unity power factor, we should at once reduce the wattless load to 750 k.v.a., and thus obtain a resulting load of 1,250 k.v.a. at 0·8 power factor without any sacrifice of efficiency. A middle-sized or large synchronous motor running at unity power factor has, generally speaking, the same efficiency as an induction motor, and the synchronous motor for 250 kw. and unity power factor is, for the same speed, a cheaper machine than the synchronous condenser for 250 k.v.a. and zero power factor. Even an induction motor with 0·9 power factor may sometimes be replaced with advantage by a synchronous motor. We can get the same power-factor correction for the system as before by running the motor over-excited with a power factor of approximately 0·9 leading.

If synchronous motors are started and brought up to speed by means of a starting motor and then synchronised, considerable skill is required for synchronising. The experience and pluck of the switch-board attendant and the steadiness of the supply frequency and voltage make an enormous difference in the time required for synchronising. Synchronising may take in plants of similar nature anything from one minute to a quarter of an hour, and even more. The synchronous motor could therefore not become popular as long as the synchronising operation on the part of the switchboard attendant was required.

If the synchronous motor is to be used on consumers' premises for doing useful work, it must be able to start easily and develop an appreciable starting torque. One of the most useful fields of application for the self-starting synchronous motor is for motor-generators. Here a comparatively small starting torque is required unless a heavy flywheel is coupled to the motor-generator. If, however, the synchronous motor has to drive a pump or compressor, even with unloading valve, the required starting torque is considerable.

Self-starting Synchronous Motors.

(*a*) **Modified Induction Motor.**—The synchronous motor works as an induction motor during starting, and it can be used either as a slip-ring or as a squirrel-cage motor. For this purpose we can either make such changes in the induction motor as will enable it to run after starting as a synchronous motor, or we can take the synchronous motor and make such additions as will enable it to start as an induction motor. The ordinary wound rotor of an induction motor can be excited, after full speed is reached, with continuous current. In order to obtain stability and overload capacity, however, it is essential to increase the air gap and get a ratio of magnetising ampere-turns to armature ampere-turns somewhere in the neighbourhood of two, while with the ordinary induction motor the ratio is somewhere in the neighbourhood of one-third. Furthermore, if we take an ordinary wound rotor which gives, say, 500 volts between the slip-rings at the moment of starting, the continuous-current exciting voltage required after synchronising will be very low. There is the alternative either to use for excitation a very small voltage and large current, or to allow an exceedingly high voltage during starting on the slip-rings and in the starting resistance.

Wound rotors of this type can be arranged with two slip-rings and "single axis" winding, which, during the starting period, carries single-phase alternating current. But the machine can then only give a small starting torque, as the pull-out torque of a single-phase rotor at full speed is only a fraction of the full-load torque of the 3-phase rotor. At half-speed the motor runs with a greater pull-out torque, which is about half the pull-out torque of an ordinary 3-phase rotor at full speed. Such a motor, if loaded to any extent, will there-

* Paper read before the Manchester Section of the Institution of Electrical Engineers.

fore tend to come up to half speed and remain there. The addition of a third slip-ring is certainly justified with such motors, and it also has another distinct advantage for running as a synchronous motor.

It is well known that a synchronous motor is liable to hunt if supplied with currents of certain periodic irregularities. These periodic irregularities may be produced by the cyclic irregularity of the prime movers. Very often it is quite impossible to know which prime movers may be called upon to supply current for the synchronous motor, and therefore it is an absolutely necessary precaution to supply the synchronous motor with dampers which, if sufficiently strong, prevent hunting even with considerable irregularities of the critical

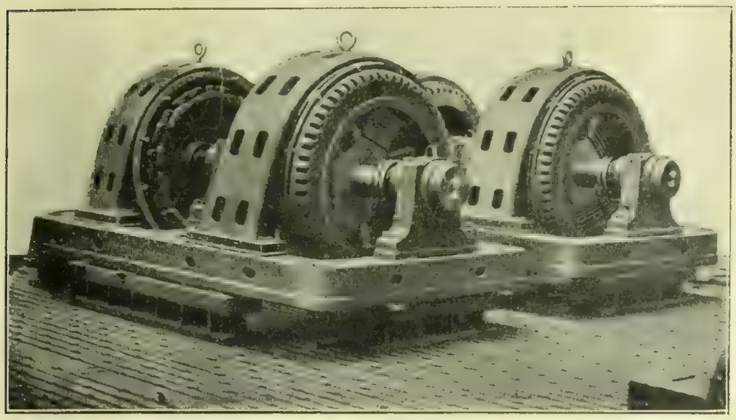


Fig. 2.—Two 300 kw. Self-starting Frequency Changers.

periodicity. A damper, to be effective, should be either a squirrel-cage or at least a 2-phase closed winding. If we arrange a 3-phase rotor in the manner shown in Fig. 1, we have a polyphase rotor winding used for continuous-current excitation, serving also as a 3-phase damper.

Fig. 1 shows a complete diagram of connections for a low-voltage motor. The stator is provided with "star-delta switch" to reduce the starting current, which otherwise would greatly exceed the full-load current owing to the large air gap. The rotor has a 3-phase winding; and two of the slip-rings are connected direct to the terminals of the 3-phase starter. The other slip-ring can be connected direct to the third terminal of the starter by pushing the lever of the "field rheostat" to the position marked "starting position." If the lever is on any of the other contacts, the exciter and the field rheostat are inserted between the third slip-ring and starter. For running, the starter is short-circuited. The exciting current flows into the third phase and is split at the star point, the two other phases each carrying one-half of the current. It is not absolutely necessary to cut the exciter out during starting, especially if a large starting torque is not required. A moderate alternating current flowing through the exciter during the starting period does no harm.

(*b*) **Salient-pole Motors.**—By far the more general and more advisable method for the design of a multipolar synchronous self-starting motor is to use the standard salient-pole magnet wheel with the standard field coils on each pole, and to provide in or near the surface of the pole-tips a squirrel cage for starting. With laminated pole-tips, slots are provided and bars of copper or some alloy inserted. Either the bars on all the poles are then connected through rings on both sides of the pole wheel, or only the bars belonging to each individual pole are connected by a copper or bronze collar going round the pole face. If solid pole-shoes are used, a special squirrel cage is not required, the solid pole-shoe in itself presenting a path for the currents induced from the stationary armature.

Fig. 2 shows two 300 kw. frequency changers built by the British Westinghouse Electric and Manufacturing Company, Ltd., each consisting of a 14-pole motor for 60 cycles coupled to a 6-pole generator for 25·7 cycles. The rotor of the 60-cycle motor (Fig. 3) has laminated poles fitted with a squirrel cage. The rotor of the 25·7-cycle generator has solid cast-steel poles and no other damper. It is quite easy, as tests have shown, to start the set either from the 60 or the 25-cycle side. Such a machine can be started with the field coils open or short-circuited. If the pole-tips were laminated and no damper existed, the voltage of an open-circuited field winding, which is wound for, say, 100 voltage excitation, would be many thousand volts, even if the stator is only supplied for starting at a fraction of the normal voltage. The action of the dampers, however, reduces the open-circuited field voltage to a considerable extent. For instance, it was measured as 570 volts between the slip-rings at the moment of starting, when the stator of the 140 h.p. synchronous motor for 2,080 normal voltage was switched on to a starting voltage of 503. Without squirrel cage the voltage of the field, calculated according to the ratio of the number of field turns to armature turns, would have been 1,200 volts. The field winding, as it were, is in the "magnetic shade," protected by the squirrel cage. Similarly the 6-pole 25·7-cycle machine of 375 k.v.a. at 500 volts, when started as a synchronous motor with 125 volts on the stator, showed a voltage between slip-rings of 1,200; while if the solid pole-shoes had no protecting effect, the field voltage, according to the ratio of turns, would be 1,700 volts. Both fields are designed for an exciting voltage of 125. If desired the voltage at start could of course be halved by arranging the excitation for 62 volts.

A quicker start can be obtained with the field coils open-circuited than with the field coils short-circuited. The dotted lines in Fig. 4 show the rapid rise in speed and the rapid decrease of the armature current when the 60-cycle machine was started with the field coils open-circuited and a voltage of approximately 25 per cent. on the stator terminals. The full lines show the starting with short-circuited field. The starting period is here nearly double the former value. The disadvantage of the increased starting period will be readily accepted if the field coils are wound for high voltage, say 440 volts. In this case tenfold normal voltage between slip-rings at the start would require special precautions. A voltage of 25 per cent. was approximately the minimum which could be used for starting the set. Even then it was necessary to use hand barring at first to overcome the friction of the bearings which are not flushed with oil. With 30 or 35 per cent. of the normal voltage no barring was required, and the set started rapidly. With a motor-generator only bearing friction and windage of the two machines have, of course, to be overcome, and the moderate flywheel effects of the two machines to be accelerated.

Fig. 5 shows the starting of the 25·7-cycle machine with cast-steel poles on 23 per cent. of normal voltage with the field coils short-circuited. In this figure also the current measured between the short-circuited slip-rings by means of a transformer and soft iron ammeter is shown. Naturally these measurements are the more unreliable the more the machine approaches synchronism, but nevertheless they show the nature of the changes in current. Just before slipping into synchronism violent oscillations could be seen on the ammeter in the field circuit: these are due to the heavy pulsations of speed immediately before synchronism, and to the nearly momentary reversal of the magnetism of each pole when one pole is slipped. These curves were only obtained by watching ordinary indicating instruments and writing the observations down at intervals of two seconds. The record must therefore not be regarded as a true oscillograph record, and especially

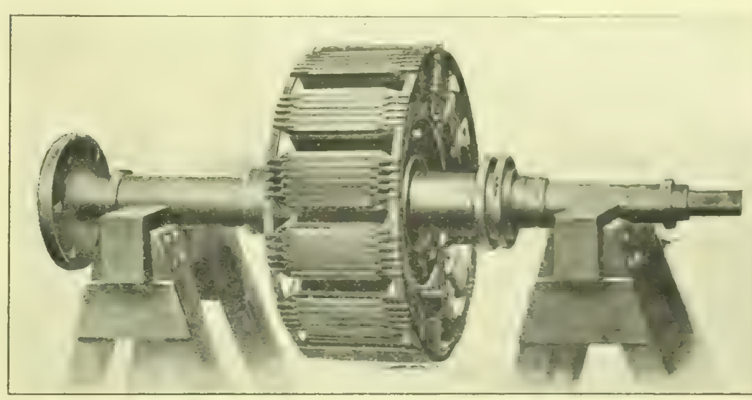


Fig. 3.—Rotor of Self-starting Synchronous Motor.

the pulsations before slipping into synchronism are by no means truly represented in the curve.

The armature ampere turns measured in the field coils correspond to approximately 36 per cent. of the total stator ampere turns at the moment of starting. When the field circuit was open the voltage across the slip-rings was 26 per cent. of the voltage, which would have been induced in the coils of a thoroughly laminated field without a squirrel cage. These tests are in good agreement with the conclusions arrived at in a paper on "Self-starting Synchronous Motors," by Carl J Fechheimer in the "Proceedings of the American Institute of Electrical Engineers," April, 1912. That paper contains a

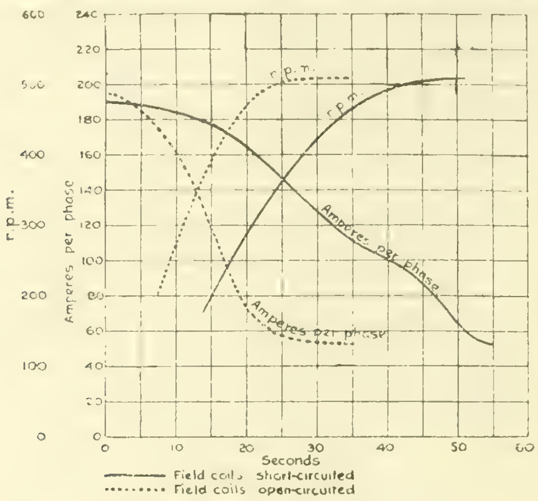


FIG. 4. SPEED AND STATOR CURRENT DURING THE STARTING PERIOD: VOLTAGE AT STATOR TERMINALS APPROXIMATELY 25% OF NORMAL VOLTAGE.

very complete investigation, theoretical as well as practical, and is considerably amplified by the discussion. It is well worth reading by anyone who wants to study the subject more closely.

I should like here to consider one point which has not been fully dealt with in Fechheimer's paper, that is, the pulling into synchronism. The starting of the motor itself can be understood fully by applying the rules for the starting of squirrel-cage motors. We know we can increase the starting torque by increasing the resistance of the squirrel cage and for a given stator voltage the torque is, within certain limits, proportional to the rotor resistance. The short-circuited field winding represents practically a second squirrel-cage winding, incomplete because it is a "single axis" (single-phase) winding, and because it is shaded to a great extent and only traversed by a part of the flux. Now this winding will reduce the starting torque in the same way as a reduction in the resistance of the main squirrel cage. It will also cause a reduction of the starting torque when passing through half synchronous speed (cf. Lamme's contribution to the discussion on Fechheimer's paper). On the other hand, the short circuited field winding will, like another reduction of the squirrel-cage resistance, enable the machine to approach nearer to synchronous speed as an induction motor; that means it will decrease the slip of the machine as an induction motor. When we have reached this speed, the theory of the induction motor is no longer applicable. One thing only is certain—the squirrel cage must bring up the rotor as an induction rotor to a certain speed near enough to synchronous speed to enable the synchronising power of the machine to accelerate the rotor from this point to synchronous speed.

PULLING INTO SYNCHRONISM.

(*a*) **Field Excited.**—Let us assume a laminated rotor excited with continuous current and of the smooth cylindrical type with distributed winding. If the rotor was stationary, and the stator connected to a polyphase supply of a given frequency, we should have during one-half of each complete cycle accelerating forces, and during the other half of each cycle retarding forces of approximately the same strength. If the rotor is running at a speed near synchronism, we may say that acceleration will take place if the vector of the electromotive force induced in the stator windings by the rotor is lagging behind the vector of the voltage impressed on the stator terminals by the supply: retardation, if the induced electromotive force is leading.

If in Fig. 6 O A represents the vector of the supply, and O B the lagging vector of the rotor, the synchronising output can be represented as follows:—

$$L = E\, I_0 \,.\, \sin \alpha,$$

where E represents the terminal voltage and $2\, I_0$ the current which flows into the stator winding of the machine if the rotor vector is in direct opposition to the supply vector O A. This formula holds good on the assumption that the value of the apparent reactance is not dependent upon the position of the rotor, and that the circuit contains negligible resistance. The maximum value of the synchronising power is given by:

$$L_{max.} = E\, I_0,$$

and the average value during the half period of acceleration by:

$$L_{aver.} = \frac{2}{\pi}\, E\, I_0.$$

If, for instance, a machine is so excited that it would take no wattless current when running at synchronism, and if the short circuit current corresponding to this excitation was equal to twice the full load current, the maximum of the synchronising power would be twice full load output. For machines with salient poles it has been proved that for small angles the synchronising power is greater than would correspond to this formula. But for an approximate calculation it will be sufficient to adopt this value.

We shall now consider a machine without any load (even friction being excluded), its rotor coupled to a flywheel and brought by some outside motive power up to a speed $(1-s)$, 1 representing synchronous speed, and s, a small value, the "slip." If the supply vector O A in Fig. 6 is kept stationary, the rotor vector O B must be considered as rotating slowly counter-clockwise. The rotor was at first unexcited. If the excitation is put on, the synchronising forces tend to reduce the slip for all positions of the rotor on the half-circle A C D, and to increase the slip for all rotor positions on the half-circle D F A.

We do not take into account at present any power the motor is able to give as an "induction motor" due to the existing slip. The effect of the synchronising forces will be that instead of a constant slip, s, a varying slip is produced with the outside values $s \pm s_1$. The minimum slip, $s - s_1$, will

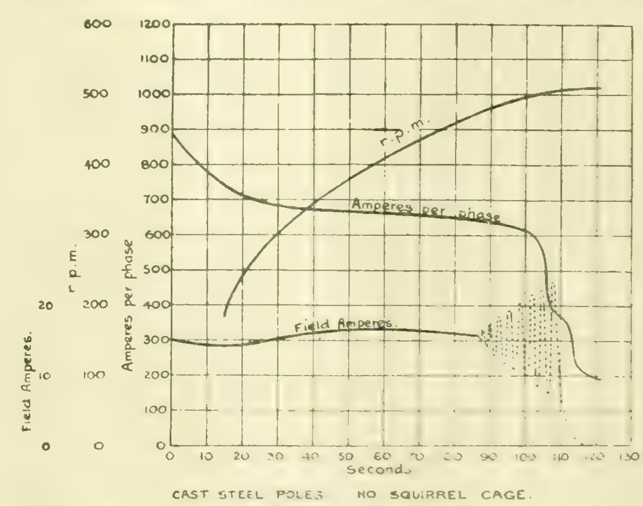


FIG. 5. SPEED AND CURRENTS IN STATOR AND FIELD WINDING DURING THE STARTING PERIOD: VOLTAGE ON STATOR TERMINALS APPROXIMATELY 23% OF NORMAL VOLTAGE.

exist when the rotor vector has the position O D in direct opposition to the supply vector O A; the maximum slip, $s + s_1$, when it is in coincidence with O A. The average slip will not exactly occur at the points C and F. To ascertain the points of average speed, we have to divide into halves the work done by the accelerating forces during the half-period represented by the semicircle A C D, and the work done by the retarding forces in the semicircle D F A. $\frac{1}{2} L_{aver.} \,.\, t/2$ will therefore represent the work done, while the rotor slip is reduced from

its normal to its minimum value, provided t designates the duration of one full-slip period. This work increases the rotor speed from a value $(1-s)$ to a value $(1-s+s_1)$, and is converted into kinetic energy.

If M is the mass of the flywheel, and v the linear speed of the radius of gyration at synchronous speed—

$$\frac{M\,v^2}{2}\left[(1-s+s_1)^2-(1-s)^2\right]$$

is the gain in stored energy. For small values of s and s_1 the above value is nearly equal to $M\,v^2\,s_1$. The amplitude of the speed oscillations which are superimposed on the average speed can now be calculated. If the periodicity of the supply be n, then the periodicity of the slip is $n\,s$, and the duration of a slip period is $t=\frac{1}{n\,s}$ secs.

Let us express the stored energy in metre kilograms and the synchronising power in watts: then we have the equation:—

$$\frac{1}{9 \cdot 8} \cdot \frac{t}{4} \cdot L_{aver} = M\,v^2 \cdot s_1,$$

$$\frac{1}{9 \cdot 8} \cdot \frac{1}{4\,n\,s} \cdot L_{aver} = M\,v^2 \cdot s_1,$$

$$\therefore s_1 = \frac{1}{9 \cdot 8} \cdot \frac{1}{4\,n\,s} \cdot \frac{L_{aver}}{M\,v^2}.$$

The smaller the average slip s, the greater will be the amplitude of the superimposed speed oscillations. As long as the slip s is great, and the machine a long way from synchronism, the oscillations will be hardly perceptible. When, however, the machine runs at nearly synchronous speed it will be tossed about, and immediately before pulling into synchronism the slip will vary from nearly $2\,s$ to nearly zero.

The limiting condition for pulling into synchronism is that the amplitude of the superimposed speed oscillation s_1 should be equal to the average slip s. That is:—

$$\text{the limiting value of } s_1 = s = \frac{1}{9 \cdot 8} \cdot \frac{1}{4\,n\,s} \cdot \frac{L_{aver}}{M\,v^2}.$$

The limit of the slip therefore which would just make it possible for the machine to come up to synchronous speed at the last moment before retardation sets in, is given by:

$$\sqrt{\frac{1}{9 \cdot 8} \cdot \frac{1}{4n} \cdot \frac{L_{aver}}{Mv^2}}.$$

Assume, for instance, a rotor with a stored energy of 50,000 m.-kg., an average synchronising power of 15 kw., and a periodicity of 50 per second, the limiting value of the slip would be:—

$$\sqrt{\frac{1}{9 \cdot 8} \times \frac{1}{200} \cdot \frac{15{,}000}{100{,}000}} = 0 \cdot 0152,$$

that is to say, 1·5 per cent. slip. The machine must therefore be brought up to a speed such that the slip is not more than $1\frac{1}{2}$ per cent., in order to allow the machine to fall into synchronism after the excitation is switched on.

The small mathematical investigation above makes it possible to calculate with some degree of certainty the condition under which a machine will pull into synchronism. In reality, of course, it is advisable to take a considerably lower value for the slip than the critical value calculated above, although I will not deny the theoretical possibility that the machine may pull into synchronism with a slip in excess of these figures. Approximately 1·4 times the above calculated value of the slip would be possible if the machine could be excited or switched on to the supply just at the moment when the rotor and supply vectors are in coincidence. Then the whole duration of half a slip period would be available for pulling into synchronism. Further, the retarding torque for a certain leading angle may be slightly less than the accelerating torque for the same lagging angle, and this would enable a machine, after coming up to a speed which the outside motive power can give, further to accelerate its speed slightly during each slip period until the critical value for the slip is reached.

Our calculation was based on the assumption that the machine is not loaded at all. In this case it was theoretically sufficient to pull the rotor up just before it actually got into direct opposition to the supply. If, however, the machine is loaded, O B for instance representing the normal lagging position of the synchronous rotor for the given load, we must pull up the rotor before it slips past the symmetrical position O B_1. If the machine is loaded and brought up to the speed $(1-s)$ by means of a squirrel cage on the rotor, the conditions for pulling into synchronism are similar. The machine is then developing at the average slip s a torque which is equal to the load torque. For the superimposed speed oscillations the squirrel cage will give us superimposed torques following the sine law, and having their positive and negative amplitude at the same moment as the speed oscillations themselves. We know on the other hand that the speed oscillations reach their amplitude when the oscillating torques which are their cause are passing through zero. We have here two kinds of oscillating forces—the synchronising torque and the squirrel-cage oscillating torque. The latter one must be represented in a diagram (Fig. 7) at right angles to the resultant of both oscillating forces. If O M represents the oscillating synchronising torque, M N the oscillating torque of the squirrel cage, then O N, at right angles to M N, represents the resulting oscillating torque. If M N is small compared with O M, the difference in size between O M and O N will be very slight. M N (corresponding to the superimposed slip amplitude s_1) naturally cannot exceed the load torque corresponding to the average slip s, and it is evident that the load torque must be very much smaller than the maximum of the synchronising torque. If M N was even 50 per cent. of O M, O N would still be 87 per cent. of O M.

The limit of the slip which still allows pulling into synchronism is therefore nearly the same in a machine which

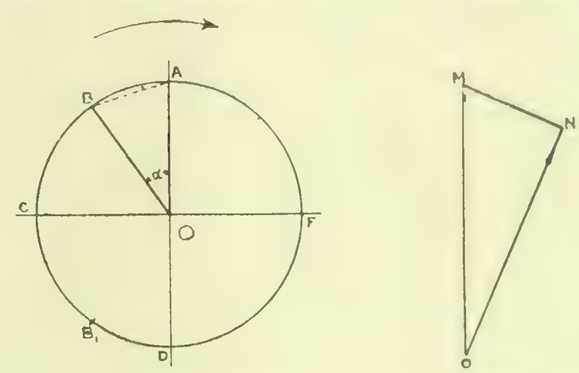


FIG. 6. FIG. 7.

VECTOR DIAGRAMS.

under a certain load runs up on its own squirrel cage as in an unloaded machine with no squirrel cage, which is brought up to the same slip by means of an outside motor. The points of maximum and minimum slip before the machine pulls into synchronism will, with a loaded machine, be shifted against A and D (Fig. 6). The limit of the starting torque for which a self-starting synchronous motor can be used is, as a rule, not the torque required for starting from rest, but the torque which can be overcome for pulling into synchronism.

If we take an ordinary synchronous motor which could take, while running in synchronism, a maximum overload of three times normal, then the average torque during one half cycle of slips would be less than twice normal if the stator of the machine were connected to the full voltage and the rotor fully excited. It is seldom permissible, however, to start a large synchronous motor on full voltage, because the starting current (which is only limited by the leakage field of the stator and by the ohmic resistance) would often be equal to 10 times the normal value. If the motor, by means of an autotransformer, is started on half voltage to reduce the starting current taken from the line to approximately $2\frac{1}{2}$ times normal, and if the rotor is excited to a value corresponding to half voltage, the synchronising power of the machine is reduced to a quarter of what it was before.

The average synchronising power will therefore be less than one-half normal power of the motor. A very small margin is therefore left if one would try, for instance, to start in such a way a pump which, running at full speed with the valve shut, takes 30 to 40 per cent. of full-load torque. For that purpose more than 50 per cent. starting voltage would have to be provided.

(*b*) **Field Unexcited.**—If a cylindrical rotor with distributed winding is not excited, no synchronising power occurs

in any position of the rotor beyond a small hysteresis torque, which is due to the fact that the maximum of the rotor magnetisation lags by a constant small angle behind the maximum of the stator field. The hysteresis torque is practically constant for very wide variations of speed, as shown already in Ewing's hysteresis apparatus. As the hysteresis torque is in ordinary machines very small, a machine with smooth cylindrical rotor does not pull into synchronism without excitation.

Machines with salient poles show a different behaviour. Also here the rotor field is produced by the stator, but due to the very high reluctance of the gaps between the salient poles the magnetic field in the rotor will be so tied to the pole pieces that the magnetic axis of each pole for the greater part of each half period will only move slightly to either side of the geometrical centre of the pole. For a great part of each slip period the machine therefore behaves nearly in the same way as a machine excited with continuous current, and will be able to draw, according to the position of the pole vector, synchronising watt currents from the line.

If the residual magnetism of the poles is small compared with the field created in the rotor by the stator, every pole will readily accept north or south magnetisation, and therefore we have no opposition of rotor and line vectors as in Fig. 6. The angles between line and rotor vectors do not vary between 0° and 180°, but only between 0° and 90°. In other words, every slip period is here replaced by two. The rotor will, as it were, hang on to the stator field for a considerable time till it lags approximately half the length of one pole, then the lines of force snap and the rotor will slip into the field of the next stator pole and hang on to this.

During the moment of snapping there is practically no rotor field to balance the voltage impressed on the stator. The stator must therefore at this moment create its field outside. At this moment the wattless current in the stator will thus be very high, and the leakage field of the stator will be so increased as to keep the impressed voltage balanced. If there is resistance or reactance in the machine circuit, this will at the moment reduce the terminal voltage.

In a machine with field excited by continuous current a considerable drop of the terminal voltage may be caused (due to resistance or reactance) for positions of the rotor vector making a large angle with the supply vector. If the rotor vector is in opposition to the supply vector the terminal voltage will be lowest.

(*To be continued.*)

NORMAND WATER-TUBE BOILER.

The accompanying illustrations show a design of water-tube boiler, the invention of Augustin Normand, 67, rue du Perrey, Le Havre, Seine, France, in which means are provided for uniformly distributing the vaporisation in the different parts of the upper reservoir and for reducing the resistance which the tubes offer to the draught. The tube walls are so arranged as to permit the gases to enter the tube nest and split up into two portions, which portions traverse the nest a distance equal to half the total length of the tube nest. Fig. 1 shows a boiler heated by petroleum from both ends and fitted with tube screens. Fig. 2 is a sectional view across a nest of tubes on line B—B of Fig. 1. Figs. 3, 4, and 5 represent similar sectional views, but with different arrangements of water tubes. The boiler comprises an upper drum and two lower drums united with the former by means of two nests of tubes which are substantially vertical. The burners are shown at R. The tubes forming the innermost row S are arranged close together in such a manner that a continuous wall is formed except at their upper and lower extremities where they are parted, and at the central portion of the boiler where a certain number of tubes S are omitted as shown in Fig. 2. The row of outer tubes T are also arranged close together in such a manner as to form a screen except in the upper part and at the two extremities of the nest where these tubes are parted. In this manner the hot gases after having circulated between the inner tubes U of the nest pass into the smokeboxes V and are discharged through flues into the chimney.

In the modification represented in Fig. 3 tubes are omitted in a certain number of rows and the space left free increases, from the exterior towards the interior of the boiler; the vacant space thus formed in the mass of the nest of tubes facilitates the penetration of the furnace gases into this nest. In the arrangement shown in Fig. 4 the row of tubes S which is near the furnace is arranged so as to permit of the entry of the gas into the tube nest at the centre, by omitting a certain number of the tubes in the tube walls the same as shown in Fig. 2, but in this instance an additional row of tubes is arranged outside the opening to the nest; the tubes being spaced in the same relation as those inside the nest.

In the arrangement represented by Fig. 5 the tubes T of the exterior rows are placed side by side so as to form a screen

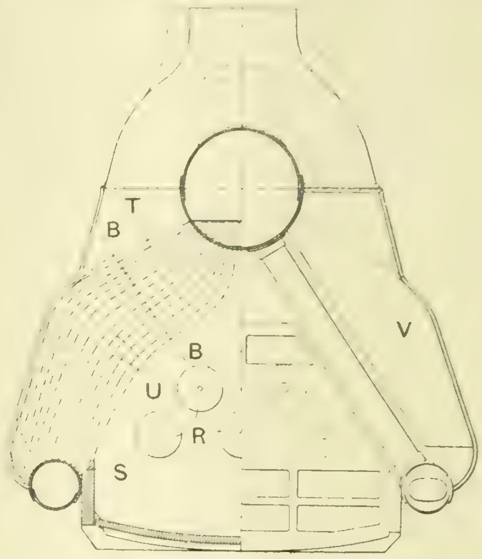


Fig. 1.—Normand Water-tube Boiler.

except in the central part of the boiler where these tubes have been parted to permit of the passage of gases to the smokebox and chimney. Moreover, a number of tubes are omitted at the ends of the rows for the admission of the hot gases and so as to facilitate the penetration of these gases into the nest. A number of tubes can also be omitted in the central part of the boiler to permit of the fitting of intermediate stays W uniting the upper drum with the lower drums.

Whatever the arrangement of the tube screens may be, it will, it is claimed, show great advantages as compared with other known systems. It may occur that, in the case of boilers of great length and especially in those heated from both ends, the area of the passage of gases between the nests of tubes is small in proportion to the volume of the combustion gases and a great resistance to the passage of these gases will

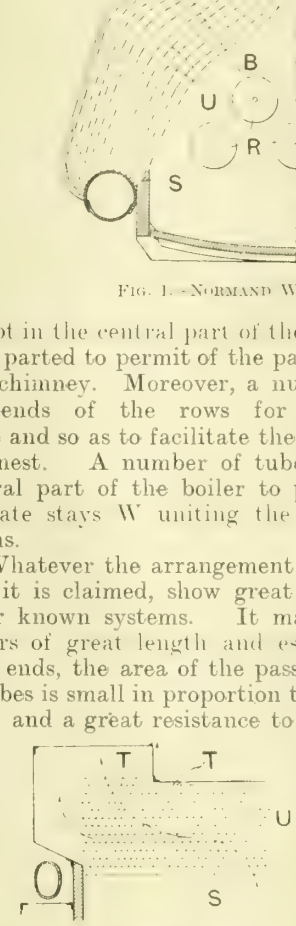


Fig. 2.

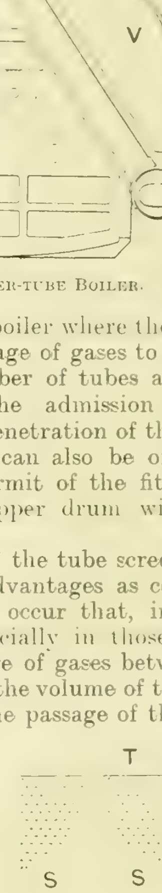


Fig. 3.

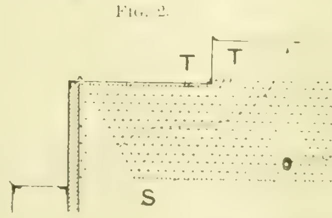


Fig. 5

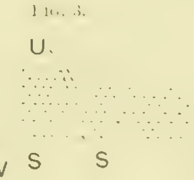


Fig. 4

Normand Water-tube Boiler.

follow therefrom. On the other hand, the tubes which are most heated being at one of the ends of the boiler the zone of the greatest vaporisation in the upper reservoir will be very small and may cause priming. With the arrangement illustrated, each part of the nest of tubes will be traversed by half the volume of gas which would pass through in the same time in the case of a boiler with a single course and the length of the course of the gases in the nest of tubes will be halved. For these two reasons, the resistance opposed by the boiler to the draught will be greatly diminished. Besides, the distribution of the most heated tubes over a greater length and above all their disposition at the two ends of the nest as in the case of Fig. 5 will effect an increase of the surface of vaporisation and will ensure a higher degree of dryness of the steam.

THE REMOVAL OF DUST FROM GRINDING WHEELS.

THE New York State Department of Labour have recently issued the following specification, prepared by Mr. William Newell, mechanical engineer to the Department, for the design, construction, and operation of exhaust systems for grinding, polishing, and buffing wheels:—

Minimum sizes of branch pipes allowed for different sized emery or other grinding wheels:

Diameter of Wheels.	Maximum grinding surface, sq. in.	Minimum diameter of branch pipe in ins.
6in. or less, not over 1in. thick	19	3
7in. to 9in. inclusive, not over 1½in. thick...	43	3½
10in. to 16in. inclusive, not over 2in. thick ...	101	4
17in. to 19in. inclusive, not over 3in. thick...	180	4½
20in. to 24in. inclusive, not over 4in. thick...	302	5
25in. to 30in. inclusive, not over 5in. thick...	472	6

In case a wheel is thicker than given in the above tabulation, or if a disc instead of a regular wheel is used, it must have a branch pipe no smaller than is called for by its grinding surface, as given above.

Minimum sizes of branch pipes allowed for different-sized buffing, polishing, or rag wheels, as they are variously called:—

Diameter of Wheels.	Maximum grinding surface, sq. in.	Minimum diameter of branch pipes in ins.
6in. or less, not over 1in. thick	19	3½
7in. to 12in. inclusive, not over 1½in. thick..	57	4
13in. to 16in. inclusive, not over 2in. thick...	101	4½
17in. to 20in. inclusive, not over 3in. thick...	189	5
21in. to 24in. inclusive, not over 4in. thick..	302	5½
25in. to 30in. inclusive, not over 5in. thick...	472	6½

Buffing wheels 6in. or less in diameter used for jewellery work may have a 3in. branch pipe. The thickness given for buffing wheels above applies to the thickness of the wheel at the centre. In case the wheel is thicker than given in the above tabulation, it must have a branch pipe no smaller than is called for by its grinding surface. Branch pipes must be not less than the sizes specified above throughout their entire length. All branch pipes must enter the main suction duct at an angle not exceeding 45°, and must incline in the direction of the air flow at junction with main. Branch pipes must not project into main duct. All laps in piping must be made in the direction of the air flow. All bends, turns, or elbows, whether in main or branch pipes, must be made with a radius in the throat at least equal to 1½ times the diameter of the pipe on which they are connected.

The inlet of the fan or exhauster shall be at least 20 per cent. greater in area than the sum of the areas of all the branch pipes, and such increase shall be carried proportionately throughout the entire length of the main suction duct., *i.e.*, the area of the main at any point shall be at least 20 per cent. greater than the combined areas of the branch pipes entering it between such point and the tail end or dead end of the system. If such increase is made greater than 20 per cent., the area of the main at any point, except that portion of it between the branch entering it nearest the fan, and the fan shall bear approximately the same ratio to the combined areas of the branches preceding that point (*i.e.*, between it and the tail end of the system) as the area of the main at the branch nearest the fan bears to the combined areas of all the branches. (This provision is made to permit the use of a fan having a larger inlet area than the area of the main at the branch pipe nearest to the fan, if desired.)

The area of the discharge pipe from the fan shall be as large or larger than the area of the fan inlet throughout its entire length. The main trunk lines, both suction and discharge, shall be provided with suitable clean-out doors not over 10ft. apart, and the end of the main suction duct shall be blanked off with a removable cap placed on the end. Sufficient static suction head shall be maintained in each branch pipe within 1ft. of the hood to produce a difference of level of 2in. of water between the two sides of a U-shaped tube. Test is to be made by placing one end of a rubber tube over small hole made in pipe, other end of tube being connected to one side of U-shaped water gauge. Test is to be made with all branch pipes open and unobstructed.

In addition to the above specifications, a number of "recommendations" are given below, which, if observed, will make for still more efficient operation and longer life of the system.

Emery wheel and buffing wheel exhaust systems should be kept separate owing to danger of sparks from the former setting fire to the lint dust from the latter, if both are drawn into the same suction main.

In the case of undershot wheels (*i.e.*, the top of the wheel runs toward the operator) which is almost always the direction of rotation of both emery and buffing wheels, the main suction duct should be back of and below the wheels and as close to them as is practicable; or it should be fastened to the ceiling of the floor below, preferably the former. If behind the wheels, it should be not less than 6in. above the floor at every point to avoid possible charing of the floor in case of fire in the main duct, and also to permit sweeping under it. For similar reasons it should be at least 6in. below any ceiling it may run under.

Both the main suction and discharge pipes should be made as short and with as few bends as possible, to avoid loss by friction. If one or the other must be of considerable length, it is best to place the fan not far beyond where the nearest branch enters the large end of the main, as a long discharge main is a lesser evil than a long suction main. Avoid any pockets or low places in ducts where dust might accumulate.

The main suction duct should be enlarged between every branch pipe entering it, whenever space permits, and in no case should the main duct receive more than two branches in a section of uniform area. All enlargements in the size of the main should be made on a taper and not by an abrupt change.

If there is a likelihood of a few additional wheels being installed in the future, it is advisable to leave a space for them between the fan and the first branch, and to put in an extra size fan. Or, a space may be left beyond the fan so that the fan may be moved along and the main extended when it is actually decided to install additional wheels, provided the fan is of sufficient size to still comply with these specifications after the additional branches are added.

Branch pipes should enter the main on the top or sides and never at the bottom. Two branches should never enter a main directly opposite one another. Each branch pipe should be equipped with a shut-off damper or blast-gate, as it is also called, which may be closed, if desirable, when the wheel is not in use. Not more than 25 per cent of such blast-gates should be closed at one time; otherwise, the air velocity in the main duct may drop too low and let the dust accumulate on the bottom.

It is very important that the lower part of the hood shall come far enough forward beneath the front of the wheel so that the dust will enter the hood and not fall outside of it altogether, even if the accomplishment of this result necessitates leaving considerable space between the wheel and the lower part of the hood, in order that the hood shall not interfere with the work.

Branch pipes should lead out of the hood as nearly as possible at the point where the dust will naturally be thrown into them by the wheels. This is very important. An objectionable practice sometimes found where small work is polished is the use of a screen across the mouth of the branch pipe where it enters the hood. Such screens are an obstruction to the passage of material and the ravellings from buffing wheels are held against the screen by the suction, with the result that in a short time the draught is almost entirely cut off.

The use of a trap at the junction of the hood and branch pipe is good practice, provided it is cleaned out regularly and not allowed to fill up with dust. This will catch the heavier particles, and so take some wear off the fan. It will also

to catch any nuts, pieces of tripoli, &c., dropped by accident, and, in the case of work on small articles, will enable them to be recovered when dropped in the hood.

All bends, turns, or elbows, whether in main or branch pipes, should be made with a radius in the throat or twice the diameter of the pipe on which they are connected, wherever space permits. Elbows should be made of metal one or two gauges heavier than the pipe on which they are connected, as the wear on them is much greater.

The withdrawal of air from a room by an exhaust system naturally tends to create a slight vacuum, and for this reason inlets for air at least equal to the sum of the areas of the branch pipes should be left open.

The cyclone separator or dust collector must be proportioned to suit operating conditions, light dusts requiring a larger separator than heavy dusts. For metallic dusts and wood shavings a separator should be selected the area of whose inlet is at least as large as the area of the discharge pipe from the fan. For light buffing dusts, lint, &c., the air outlet from the top of the separator should be so large that the velocity of discharge will not exceed 300ft. to 480ft. per minute; then select a separator of which the other dimensions are proportionate. The air outlet should be provided with a proper canopy or elbow to exclude the weather, but should be otherwise unobstructed. There should be ample clearance under the separator for the accumulation or storage of the dust, which should never be allowed to pile up as high as the bottom of the separator.

STANDARDS FOR EMERY WHEELS.

Mr. Chas. G. Smith, of the Pittsburgh Emery Wheel Company, in a recent issue of "The Iron Trade Review," directs attention to the desirability of standardising emery-wheel shapes and steel safety collars. Unless such a standard was adopted and complied with, the use of safety-shape wheels and safety collars would, he observed, increase rather than decrease the hazard of the operation of these wheels. Many users of grinding wheels recently had undertaken to make their own safety collars, and many of these did not conform to any of the standards on the market. In addition, some manufacturers of grinding wheels would make these collars to conform to any shape. This practice should be stopped. Formerly, his company tapered its collars $\frac{3}{4}$in. per foot, the wheels having been tapered on both sides. Many of these collars were made with a 6in. flat spot at the centre. This had been changed to a 4in. flat spot in the collars, and all wheels now had a 6in. flat spot. One emery-wheel manufacturer formerly tapered collars $\frac{1}{2}$in. per foot with a 4in. flat spot, but some years ago this taper was changed to $\frac{3}{4}$in. to the foot with a 4in. flat spot. Another grinding wheel company tapered its collars $\frac{3}{4}$in. to the foot, and some of these had a 4in. and others a 6in. flat spot.

The writer referred to a number of instances where wheels with a $\frac{1}{2}$in. taper had broken and large pieces became disengaged from the collars, resulting in the injury or death of the operators. On the other hand, wheels tapered on both sides with a taper of $\frac{3}{4}$in. per foot, protected by collars which fitted the wheel, the collars being 4in. less in diameter than the wheel, had resulted in practically no casualties or serious damage during the 10 years that this taper had been adopted. Nearly every wheel tapered $\frac{3}{4}$in. would, he remarked, break when protected with collars having a $\frac{1}{2}$in. taper, and the broken pieces of the wheel would become disengaged from the collars, which would open at the rim. A wheel with sides tapered $\frac{1}{2}$in. per foot would not necessarily break if used in collars with a $\frac{3}{4}$in. taper, but the constant use of $\frac{1}{2}$in. tapered wheels and $\frac{3}{4}$in. tapered collars would ruin the collars for subsequent use for $\frac{3}{4}$in. tapered wheels. This was due to the fact that the collars would spring in the centre as a result of the tightening of the nut on the spindle. If more than 2in. on the wheel was to be exposed beyond the safety collar, a safety hood should be mounted on the machine in addition to the collar. In conclusion, he remarked that if all manufacturers of wheels would give them a taper of $\frac{3}{4}$in. to the foot with a $6\frac{1}{2}$in. flat spot, and if they would make all collars for wheels with a $\frac{3}{4}$in. taper with a 4in. flat spot, and if all users of emery wheels who make their own collars would conform to this standard, no further difficulty would be experienced. These specifications applied to wheels more than 12in. diam. For grinding wheels 12in. and less in diameter, the company with which he is connected would hereafter adopt a 3in. flat spot, thereby permitting the use of collars 6in. diam. This did not apply to 12in. stubs of larger wheels. If users of grinding wheels would insist on a $\frac{3}{4}$in. taper per foot with 6in. flat spots, a standard could easily be established.

ROTORS FOR CENTRIFUGAL PUMPS AND COMPRESSORS.

A design of rotor for centrifugal pumps and compressors is shown in the accompanying cuts. It has been designed and patented by Messrs. Escher, Wyss, and Co., Zurich, Switzerland, and has the lateral face which is adapted to receive the blades constructed in the form of a hyperboloid. As is well known a hyperboloid is produced by the rotation of a straight line about an axis without changing its position with regard to that axis. By so choosing this position as to cause it to coincide with the position of the blades to be secured to the rotor the great advantage is obtained of enabling straight blades to be used which are cheaper and easier to manufacture, particularly on a large scale, than curved blades and which can be secured to the disc in a simpler and safer manner without necessitating the time-wasting operation involved in the usual setting and fitting. Straight blades have already been used, for instance, in compressors, but in this case the faces of the rotor destined to receive the blades had to be straight. Curved rotor faces, however, have over straight faces the advantage of forming a better guide for the air and of enabling a more favourable shape to

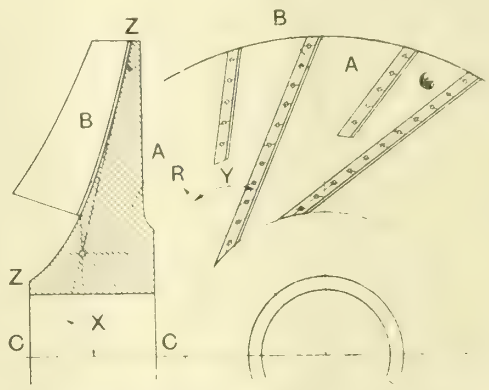


Fig. 1. Fig. 2.
Rotors for Centrifugal Pumps and Compressors.

be given to the rotor to counteract strains, and more particularly to avoid the bending strains which are liable to occur in rotors with one-sided admission.

The illustrations show the rotor of a centrifugal compressor with one-sided admission. The straight blades of an angular or T-shaped cross-section are to be riveted to the rotor A. In cross-section, as shown in Fig. 1, the blades should form an angle X with the axis C, while viewed in lateral elevation according to Fig. 2 they should form the angle Y with the radius R so that in reality these blades are entirely oblique with regard to the axis C. In precise coincidence with this direction a straight line should now be rotated about the axis whereby the front profile of the rotor is determined and which profile therefore assumes the form of a hyperboloid. Precisely registering with the position and direction of the generatrix, the blades B to be riveted to the rotor are then put in place. These blades need not all have the same length, although as regards the axis they must all have the same direction. The rear face of the rotor may likewise receive the form of a hyperboloid or that of any other rotary face or even be straight, if desired. In the event of the rotor being subject to admission on both sides, both faces are shaped as hyperboloids, so as to enable straight blades to be secured to both faces. The turner will of course be provided with a gauge corresponding to the sectional face Z Z of Fig. 1 of the hyperboloid and with regard to the axis presenting a convex curve.

Modern Developments of Aeroplane Theory.—A paper on this subject will be read by Mr. Archibald Low, M.A., at a meeting of the Junior Institution of Engineers, to be held at the Institution of Electrical Engineers, Victoria Embankment, on Wednesday evening, April 23rd.

STUDIES OF THE CUPOLA MELTING PROCESS.

The cupola melting process is the subject of a paper in "Stahl und Eisen" for January 30th, 1913, by Dr. F. Hüser, of Griesheim-am-Main, and we are indebted for the following abstract to our contemporary "The Iron Age."

The tests were carried out on the cupola shown in Fig. 1, which has two tuyeres, one in front 70 mm. by 190 mm. (2·75in. by 7·48in.) and one behind 130 mm. by 500 mm. (5·12in. by 19·68in.), their total cross-section being one tenth that of the furnace. The blast is taken from a common blast main serving four furnaces: it is furnished by a fan and is regulated by a throttle valve. The pressure on starting was 7·96 oz. per square inch; as the tuyeres slacked up it increased so that in about an hour it was about 13·64 oz. and during the remainder of the test it varied between 13·64oz. and 15·91oz. Measurements of the volume of blast gave an average for three days of 19·686 cub. ft. per second. More blast is received at the beginning, because as the melting goes on the tuyeres decrease in area and the column of charge becomes dense. There is more opposition therefore to the blast, and the fan does not furnish so much; in other words, its efficiency drops with increased opposition. The loss of blast through leakage in the joints, &c., and oxidation of iron, manganese, silicon, phosphorus and sulphur was found to be an average of 16 per cent. At the beginning it was lower but increased at the end to 20 per cent.

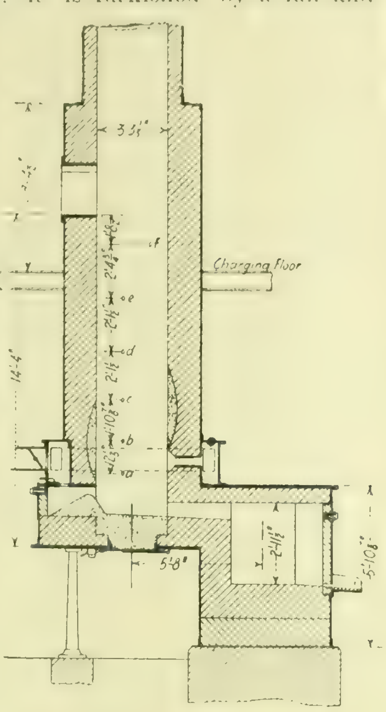


Fig. 1. Section through the Cupola.

Gas and Temperature Conditions.—In order to determine these conditions in the different parts of the furnace holes were bored through the shell and lining in the six places shown in Fig. 1. Detailed tables are then given of the analysis of the gases taken from the different holes, and a description of the arrangement used for taking the samples. No correct samples could be obtained from hole *a* because it continually kept closing up. The CO_2 percentages are shown graphically in Fig. 2. Samples of the waste gases were taken by means of a pipe, penetrating about 16in. into the charge. The average sulphur of four tests taken on different days was 0·978 g. per cubic metre (0·43 g. per cubic foot). The temperatures were measured by a Le Chatelier couple as far as possible, but for the two lower zones a Wanner optical pyrometer was used, mounted in a special air-tight arrangement which is described. Hole *b* could not be kept free from slag very long, and at hole *a* the measurements were still more difficult to make, and are not included in Fig. 3, which shows the temperature graphically. From Fig. 3 it is seen that in the first part of the campaign zone *d* is still within the melting zone, which is due to the height of the coke bed. Zone *c* is continually within this melting zone, which is also shown by the strongly slagged walls of this part of the furnace. The gradual decrease of the temperature here leads to the conclusion that the coke bed slowly decreases in volume.

Table I. Iron Tests.

No.	Time from beginning Hr.	Min.	Blast. Oz. per Sq. In.	Position.	C	Si	Mn	P	S
1		20	8·88	Channel....	3·50	1·82	·68	·626	·164
2		35	10·92	Channel....	3·55	1·97	·67	·626	·146
3	1	00	13·43	Spout beg.	3·38	2·01	·56	·630	·116
4	1	00	13·43	Spout end	3·38	1·99	·51	·665	·114
5	1	15	13·43	Channel....	3·36	2·18	·61	·708	·112
6	1	30	13·43	Spout beg..	3·31	1·98	·54	·690	·104
7	1	30	13·43	Spout mid..	3·39	2·07	·53	·656	·094
8	1	30	13·43	Spout end..	3·36	2·13	·57	·686	·104
9	1	55	14·56	Spout	3·36	2·22	·61	·673	·104
10	2	00	14·68	Channel....	3·33	2·31	·61	·646	·116
11	2	25	16·38	Spout	3·38	2·16	·58	·690	·112
12	2	35	15·91	Channel....	3·36	2·27	·62	·693	·088
13	3	00	17·41	Spout	3·32	2·25	·58	·698	·112
14	3	15	17·75	Channel....	3·33	2·39	·61	·682	·102
15	3	20	17·98	Spout	3·31	2·29	·59	·617	·116
16	3	45	18·66	Channel....	3·29	2·44	·63	·682	·116
17	3	50	18·66	Spout	3·31	2·25	·59	·700	·118
18	4	00		*Channel....	3·08	2·40	·58	·715	·124
				Average ..	3·35	2·17	0·59	0·672	0·115

*Last few drops.

The melting zone covers the large extent of about one metre above the upper corners of the tuyeres. The blast does not go straight through to the centre of the furnace from the tuyeres, but presses upward and only gradually makes its way inward. The best arrangement of the tuyeres would appear to be one where they occupy a small height, and where each tuyere is inclined downwards, so that the blast penetrates in a curve and reaches the centre at about the height of the tuyeres. This ideal condition will be strongly influenced by slagging, but experience has shown that combustion will be very complete and the melting zone limited to its smallest amount. About half of the bed coke is placed in position three hours before starting and is brought to a clear red heat; the remainder is added half an hour before starting and is therefore well pre-heated. When the blast is admitted the whole amount is soon raised to incandescence. This explains the results shown in Fig. 4, giving the analysis of the waste gases. The complete combustion (formation of CO_2) shown at the beginning changes very quickly, so that in barely three to four hours the relations of CO_2 and CO are directly

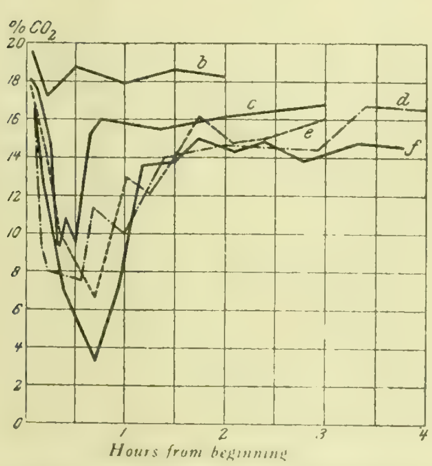


Fig. 2.—Carbon Dioxide in Volume per cent. of the Gases from the Different Holes.

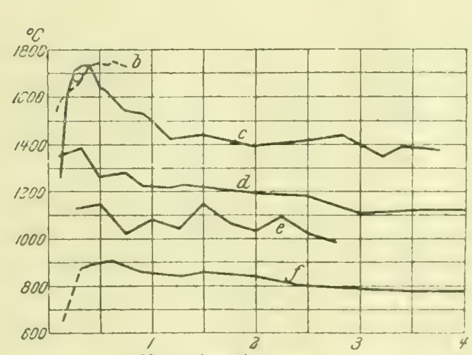


Fig. 3.—Furnace Temperatures at the Different Holes.

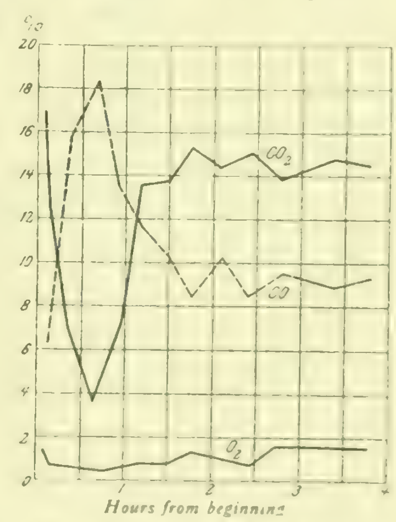


Fig. 4.—Analyses [illegible]

reversed. In 42 minutes the CO_2 drops to a minimum of 3·4 per cent., while the CO climbs to a maximum of 18·3 per cent. At this time the conditions are those of gas producer practice, with a strongly reducing influence. The further the coke bed burns down the smaller is the reducing influence of the layers of coke. The gas, therefore, becomes richer in CO, and after about two hours a state of equilibrium is reached, the amounts of about 14·5 per cent. CO_2 and 9·3 per cent. CO

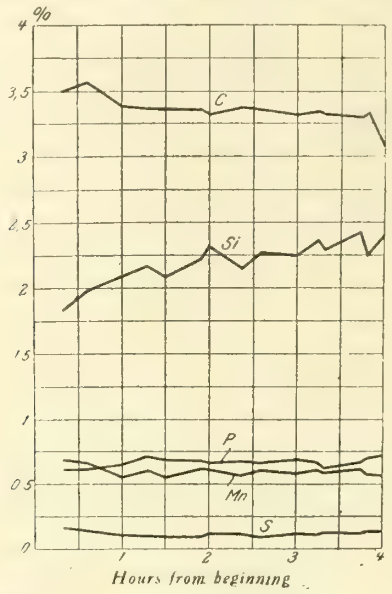


FIG. 5.—COMPOSITION OF IRON AT DIFFERENT STAGES OF THE HEAT.

not changing much thereafter. From Fig. 2 it is seen that combustion in the tuyere zone is tolerably complete (zone b), the CO_2 produced here being reduced in the upper zones.

Liquid Products of the Furnace.—Details are given of the kind of material and amount used for patching the furnace before starting, the bed coke, the limestone, and the metal charge, analyses being given in all cases. The average analysis of the charge was: C., 3·30 per cent; Si., 2·52 per cent.; Mn., 0·72 per cent.; P., 0·68 per cent.; S., 0·059 per cent. The coke had 1·11 per cent. sulphur. Besides metal the furnace gives in this experimental run 1,330 kg. of slag = 5·22 per cent. of the weight of iron; and at the end when the bottom was dropped 120 kg. of coke was left. During the whole run, which lasted four hours, tests of the metal were taken every 15 to 20 minutes and of the slag every 40 minutes with a long handled wrought-iron spoon lined with loam and graphite. The results are given in Tables I. and II. "Channel" means the channel between the furnace and the forehearth, while "spout" means the tapping spout.

TABLE II.—*Slag Analysis.*

No.	Time from beginning. Hr. Min.	Blast Oz. per Sq. In.	Position.	Appearance.	SiO_2 per cent.	FeO per cent.	Al_2O_3 per cent.	CaO per cent.	MgO per cent.	MnO per cent.	P_2O_5 per cent.	S. per cent.
1	35	10·92	Channel..	Greenish black........	43·32	11·09	12·30	28·52	1·42	3·32	0·087	0·297
2	1 15	13·43	Channel	Brownish black	45·37	24·50	13·25	12·36	0·66	3·37	0·362	0·271
3	2 00	14·68	Channel..	Brownish black	47·00	23·72	11·47	13·61	0·73	3·73	0·433	0·258
4	2 35	15·91	Channel..	Brownish black	48·21	21·35	11·68	14·76	0·78	3·52	0·346	0·248
4a	2 45	16·38	Spout ..	Brown-greenish black..	47·51	20·39	12·04	15·41	0·71	3·32	0·374	0·249
5	3 15	17·75	Channel..	Brownish black	51·18	18·35	11·05	15·23	0·71	3·59	0·333	0·234
6	3 45	18·66	Channel..	Brownish black	50·66	17·59	12·76	16·10	0·80	3·16	0·311	0·217
7	4 00	0	Channel..	Brown-greenish black..	62·35	15·45	8·11	10·61	0·70	2·91	0·229	0·241
			Average channel	....	47·62	19·43	12·09	16·76	0·85	3·45	0·312	0·254

The results are also shown graphically in Figs. 5 and 6. Silicon, sulphur, and carbon show the greatest changes. From the C line of Fig. 5 it is seen that at the beginning the carbon rises a little, which is due to the drops of metal having to pass through the large amount of fuel in the coke bed. After about the first hour it remains uniform until the extreme end, when the atmosphere in the furnace is strongly oxidising. The silicon shows a continuous slow increase, and Fig. 6 shows the connection between this fact and the slag analysis. In the first hour the silicon loss is the greatest, being slagged off by the lime in the coke bed. It amounts to 37 per cent., but the average loss is only 14 per cent. Towards the end the slag is higher in silica because of the slagging of the lining which protects the silicon, so that only 7 per cent. is lost. The lime in the coke bed appears to work directly the opposite in the case of manganese. In the first three-quarters of an hour the loss is only 3·5 per cent., but with decreasing lime and increased CO_2 in the gases this increases so that during the further course of the charge the loss averages 22 per cent. The average increase in sulphur is 95 per cent., but at the beginning it is as high as 160 per cent., due to the bed coke.

Finally, the material and heat balance-sheets are carefully worked out. The results of the first per 100 kg. iron, in per cent. by weight of the iron charged, are:

Charged.		Obtained.	
Iron	100·00 kg.	Iron	98·90 kg.
Coke	8·88 kg.	Slag	5·22 kg.
Limestone	2·10 kg.	Gases	83·81 kg.
Blast and moisture	77·08 kg.	Steam	0·31 kg.
Patching material	0·71 kg.	Dust	0·53 kg.

The results of the latter are:

Heat supplied.	Per cent.	Heat obtained.	Per cent.
Combustion of coke	89·56	In the iron	59·95
Combustion or loss of iron constituents	8·95	In the slag	5·55
		In the gases	30·11
Heat carried in by charge ..	0·60	In the steam	0·59
Heat carried in by blast ..	0·89	In dust	0·13
	100·00		96·33

The difference of 440,220 calories, or 3·67 per cent., represents heat given to the furnace walls and lost by radiation.

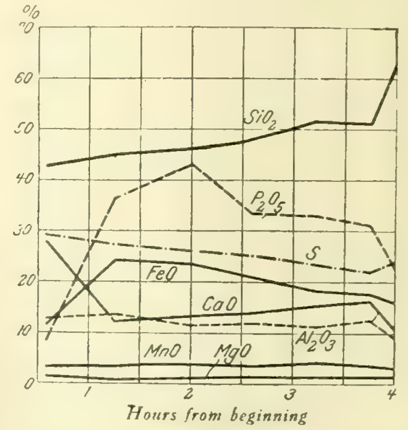


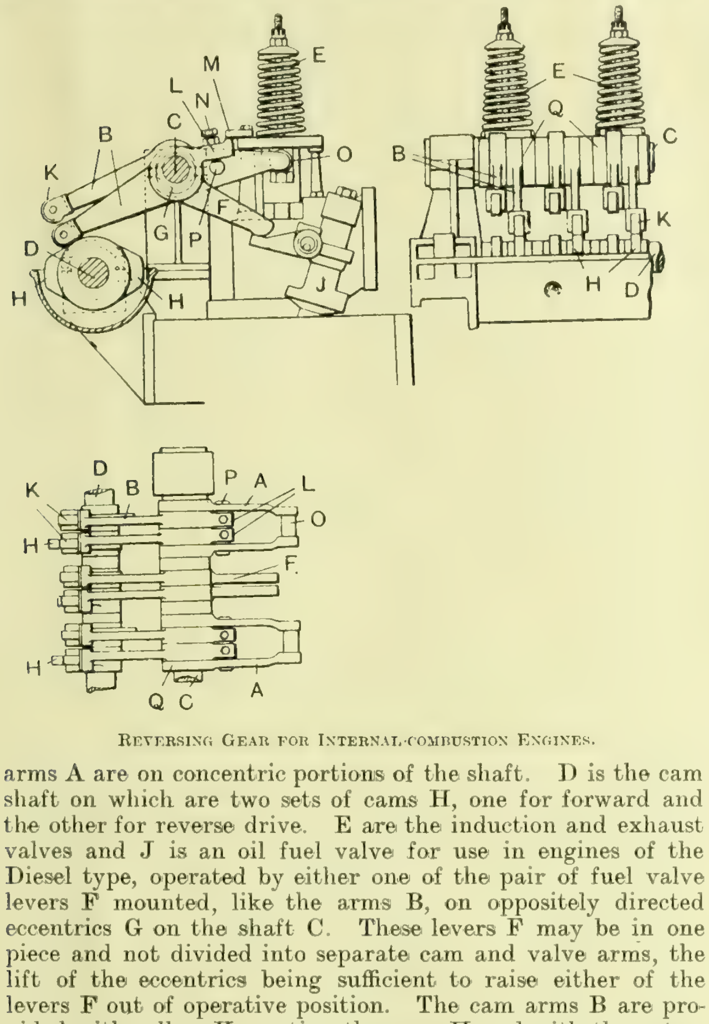
FIG. 6.—COMPOSITION OF SLAG AT DIFFERENT STAGES OF THE HEAT

From these results the heat contained in the iron proves to be 60·8 per cent. of that supplied by the combustion of the coke and the constituents of the metal.

Water Power Development in Switzerland.—Work has commenced, according to "The Electrical World," on a 15,000 h.p. water-power plant at Martigny, in the canton of Wallis, Switzerland, to utilise a fall of 5,400ft., making this station the highest-head water-power plant in the world. Special interest attaches to the penstock lines, which are three miles in length. The turbines of the Pelton type will have a total rating of 15,000 h.p., and will be furnished by Piccard, Pictet, and Co., of Geneva. Of some interest is the fact that with the 5,400ft. head available at this plant only about 30 cub. ft. of water per second will be necessary to develop the full 15,000 h.p. output of the station.

REVERSING GEAR FOR INTERNAL-COMBUSTION ENGINES.

THE reversing gear shown in the accompanying views has been patented by Mr. James McKechnie, of Vickers, Ltd., Naval Construction Works, Barrow-in-Furness, and is for use with internal-combustion engines of the type in which two cams are employed for each operation, one serving for forward and the other for reverse driving, and a cam operated member which actuates the valve lever is brought into contact with either cam according to the direction of driving. A are the valve operating arms of the induction and exhaust valve levers of which B are the cam arms, one pair for each valve arm. C is the fulcrum shaft on which both sets of arms are mounted, the eccentrics G carrying the cam arms B, while the valve



REVERSING GEAR FOR INTERNAL-COMBUSTION ENGINES.

arms A are on concentric portions of the shaft. D is the cam shaft on which are two sets of cams H, one for forward and the other for reverse drive. E are the induction and exhaust valves and J is an oil fuel valve for use in engines of the Diesel type, operated by either one of the pair of fuel valve levers F mounted, like the arms B, on oppositely directed eccentrics G on the shaft C. These levers F may be in one piece and not divided into separate cam and valve arms, the lift of the eccentrics being sufficient to raise either of the levers F out of operative position. The cam arms B are provided with rollers K meeting the cams H and with the extensions L projecting beyond their fulcrum and abutting against the fixed stop M. This stop acts as a fulcrum when an arm is raised by its eccentric G, so that the roller K is lifted clear of its cam, as shown, one member of each pair of cam arms being in operative position while the other is raised. The extension L serves to actuate the valve arm A through the adjusting screw N bearing against the cross pin P on the arm A. The arm A is shown double, with the two side members connected by the valve operating roller O, the bosses Q of the arm members being mounted on concentric portions of the shaft C on each side of the pair of eccentrics belonging to the corresponding cam arms B. By turning the shaft C through half a revolution the cam arm members which were in operative position are raised and the previously raised members are lowered on to the second set of cams, so that the valve levers are at once set for the reverse drive.

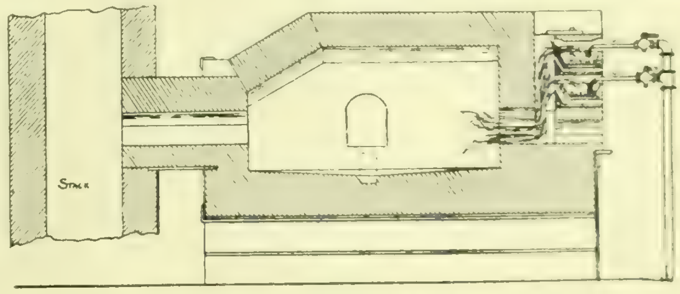
OIL REVERBERATORY FURNACE FOR MELTING NICKEL.

THE melting of nickel, either for the manufacture of nickel anodes or for rolling into sheet, has always been a difficult matter, although special crucible furnaces have been used by some manufacturers. The ordinary crucible furnace, employed for melting brass, is not suitable, as there is not sufficient heat generated for the purpose. There has recently been placed on the market a reverberatory furnace for melting nickel, which has been attended with excellent success. Although primarily intended for melting nickel, however, this furnace has been adapted for melting other metals and for calcining, roasting and other purposes.

The accompanying illustration shows a cross section of the furnace, for which, along with the following description, we are indebted to "The Brass World." It is designed for burning fuel oil, but is unique in that it employs no blast of air or steam for promoting the combustion of the oil, but makes use of the natural draught of an ordinary stack in the same manner that it is utilised for burning coal or coke. Ordinary fuel-oil is used, and it is stated that low grade oils, which are difficult to use in other forms of furnace, may be utilised. The oil is led to the burners in a pipe, and is made to flow either by gravity or by pressure from an underground tank. The burners used are of a special type invented by Mr. Gamm. They are of cast iron and of a shallow pan design. The oil flows into them, is immediately volatilised by the heat, and burns in the combustion chamber of the furnace. The novel feature of the furnace is the air duct underneath the burner to allow the entrance of air for the purpose of forming complete combustion. By this means, it is possible to burn the oil so that the maximum heat possible is obtained.

With the burner it is possible to obtain a heat up to 4,000 Fah. The oil is carried, after it has volatilised from the burner, and forms a rich, hydrocarbon gas, between two currents of air by the natural draught of the chimney, and drawn into the narrow combustion chamber, where it is burned with complete combustion. One of the novel features of the furnace is the method of controlling the air so that perfect combustion results. In oil furnaces of previous types, in which the fuel was burned by natural draught, the air was not under control, and the result was an incomplete combustion and a carbon deposit around the burners and passages. It is claimed by the makers of this type of furnace that the oil is so completely consumed, no carbon deposit at all forms. The temperature of the flame is controlled by changing the air inlets, and also by the cold air inlet in the escape flue, thus reducing the draught. A stack, of course, is necessary for operating this type of oil furnace, but one of medium height only is necessary. From 50ft. to 75ft., depending upon the location, is ample. It is a remarkable fact that only a light draught is required, and this is quite an important advantage in the treatment of fine material, where a blast would cause it to be blown away. It is stated that no trouble is experienced in working oxides that have passed through a 30-mesh sieve. Dust chambers are, therefore, unnecessary when the furnace is employed for this class of work.

The metal is melted upon the bed of the furnace by the oil flame, which passes over it in a direct manner, after which it goes to the flue. The charging door is at the side of the furnace, and the metal is tapped out. The bed of the furnace



GAMM OIL REVERBERATORY FURNACE FOR MELTING NICKEL.

is inclined towards the tap hole, so that the metal will run out easily when the tap hole is opened. One of the features of the furnace lies in the absence of danger from any overflow of oil. This might take place in the furnace on account of opening the oil valves too far. The oil then overflows the pans. The oil simply flows into the air passages and burns, generating a large volume of flame, but doing no damage. To start the furnace, the oil is allowed to flow into the pan, and then a small piece of burlap or waste is lighted and thrown on the surface. The oil begins to burn, and as soon as the pan becomes warm, the combustion proceeds in the regular manner. Like all large masses, the furnace takes some time to heat, but

this fact is true of any fuel and any large furnace. The heat generated in the furnace is sufficient for melting all commercial metals, and nickel, which, as is well known, is one of the highest melting metals, is easily melted and reduced to a fluid condition, and poured into any desired form, either in sand or metal moulds. It is now being used very successfully for the casting of nickel anodes.

A furnace of this type is used by the International Nickel Company at Bayonne, N. J., for melting nickel, and this is the largest furnace in existence for this purpose. In it 70,000lbs. of nickel are melted at a time. This size, however, is exceptional, and the makers build furnaces as small as 500lbs. for commercial work, and, in fact, it is designed to meet any requirement, from the smallest 500lbs. requirement up to the largest size previously mentioned. The furnace is equally well adapted for melting copper, German silver, bronze, and brass, and, in fact, any other material which is difficult to melt in the ordinary way. It may be of interest to state that glass is very readily melted in the furnace. The manufacturers of the furnace are now engaged in designing smaller types of furnaces, in which crucibles will be used so that founders will then be able to utilise, when necessary, all the advantages of crucible melting when the matter of hot metal for making small castings is required.

THE LONGITUDINAL STABILITY OF SKIMMERS AND HYDRO-AEROPLANES.*

BY J. E. STEELE, B.SC.

SKIMMERS and hydro-aeroplanes are of such growing interest to the naval architect that even the following short notes on the longitudinal stability of such craft may not be out of place here. The investigation is limited to the consideration of the longitudinal stability of the machine—classing skimmer and hydro-aeroplane under the one heading—when wholly or in part water-borne. This is the case all the time with the skimmer, but only part of the time with the hydro-aeroplane. When the latter leaves the water and is altogether air-borne, it is an aeroplane pure and simple, and has passed beyond the sphere of the naval architect into that of the aeronautical designer, and, therefore, beyond the scope of the present paper.

Before discussing the various classes of machine which come under one or other of the headings of skimmer or hydro-aeroplane, it would be well, perhaps, to define the terms used in connection with the stability which it is proposed to investigate. The usual term in aeronautics for movements in the plane of symmetry of the machine is "longitudinal or symmetrical dynamical stability." To the naval architect, however, the term "dynamical stability" conveys quite another meaning, viz., the work done in inclining a vessel to a given angle. It is proposed, therefore, for the purpose of this paper, to substitute the expression "longitudinal or symmetrical kinetical stability." This stability may be defined as follows: Suppose a machine to be in steady motion in the plane of symmetry which contains the centre of gravity and the line of flight, and the external forces acting on the machine to be in equilibrium. If now the machine be tilted either up or down in this plane, the forces will no longer be in equilibrium, but will constitute a longitudinal righting or upsetting couple, as the case may be. If a righting couple acts the body will return to its original position of equilibrium, and will probably oscillate about that position. If it returns to the original position without oscillation, or if any oscillations set up gradually die out, then it is kinetically stable. If, on the other hand, the oscillations get larger with time, it is kinetically unstable.

A machine may have automatic stability, that is, stability attained by the use of moving parts such as gyrostats, pendulums, &c., or may be stable in its design. This inherent stability is the only kind dealt with here, and any displacement from a position of equilibrium, due to an alteration of the rear elevating plane, or an increase in the propeller thrust, of course produces unbalance of the forces; but this is quickly followed by dynamical equilibrium under the new régime. When an aeroplane is struck by gusts of wind its behaviour depends to a great extent on its inherent stability. If it be inherently stable, then oscillations set up by the gust will be quickly damped out, and the aeroplane will revert to its state of steady motion. If, however, the gusts be periodic and synchronise with the free oscillations of the aeroplane, the results may be disastrous. If the machine be kinetically stable, that is to say, if its free oscillations have a modulus of decay, then the theory of forced oscillations shows that the forced oscillations will not exceed a certain limit. Lateral or asymmetrical stability is not dealt with here, as this is mainly of importance when the machine is altogether in the air, and beyond the range of this paper.

A machine may be a double-lifting system, one in which there are two lifting surfaces or sets of superposed surfaces, one forward and the other one aft. Or it may be a single-lifting system, in which case the auxiliary surfaces, such as tail planes, must be neutral, that is, parallel to the direction in which the wind blows on them. Three types are dealt with in which there is a gradual evolution from the skimmer on the surface of the water, viâ the machine designed to fly with its tail on that medium, to the machine which rises from and alights on the water but is otherwise an aeroplane.

We will now consider each type in detail, together with some of the problems to which they give rise. First comes the skimmer, a type of craft whose displacement at high speeds is very much less than the weight of the vessel, and which, as its name indicates, skims over the surface of the water rather than ploughs its way through it. "Miranda IV.," designed by Sir John I. Thornycroft with phenomenal success, is taken as an example of this type of boat.

"Miranda IV." — This vessel (Fig. 1) is 26ft. long by 6ft. broad, and is 2ft. 6in. in depth. The fore end is moulded to the usual form of a high-speed motor-boat. As amidships is approached her lines deviate from the ordinary, and are modified to enable the vessel to skim at high speeds, but this modification is as small as possible in order that she may be driven with ease at speeds below the skimming phase. When running at skimming speeds only that portion from A to B, and again aft of C, are water-borne, and as this is the condition which affects the present paper, only those parts of the hull need be considered. As will be seen from the drawings, the portion of the bottom from A to B forms a dihedral angle, rounded at the apex, and increasing in magnitude as we go aft. Aft of C the bottom may be taken as being flat.

When running within her skimming phase (Fig. 2) the forces acting on the boat are the weight W, the propeller thrust T, the reaction (R_F) of the water on the "forward plane" A B, and (R_A) that on the "after plane" C D. These reactions act at the centre of pressures of their respective planes, and knowing W, T, R_F and R_A in magnitude, position, and direction, it is easy to find the same three things with respect to the remaining force acting on the boat, that being the reaction (R_W) of the wind on the out-of-water portion. The reactions R_W, R_F, and R_A combine to give the common resultant R, which must pass through O, the meeting point of the remaining forces W and T.

From what follows it will be seen that an increase in the propeller thrust will cause the boat to rise forward. The three forces R, T, and W are in equilibrium (Fig. 3), and T acts at a constant angle θ to the boat, the angle between R and T being therefore constant and equal to $90° - \theta$. The point A, then, lies on the circumference of the segment of a circle containing the angle $90° - \theta$. It will be seen from this that if the thrust of the propeller be increased as shown, the boat will be tilted up forward. Strictly speaking the above can only hold if T, W, and R all pass through the same point, fixed relatively to the vessel, whatever be the inclination to the horizontal. This cannot hold for W and T unless the latter be central, that is, pass through G. For a flat plane R would generally move forward with a decrease in the angle of attack, and aft when the angle of attack is increased. If the rising of the fore end of the vessel be considerable, the increased angle of attack both of the wind and the water causes the centres of pressure of the planes to travel aft, with the result that R no longer passes through O, but constitutes a clockwise couple tending to bring down the fore end of the vessel until R again passes through O and the cycle recommences. This is one of the causes of pounding, which, besides being severe on the boat, is uncomfortable for those on board. The dipping will be excessive if the period due to skipping

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synchronises with the natural pitching period of the boat, as then forced oscillations will be set up.

The after plane, with its reaction R_A, could be done away with, but then the resultant of the wind and water pressure would be much more readily affected in direction by an inclination of the vessel, and so give rise to unbalance in the forces. The arrangement shown is much more stable, and the reaction R_A has the advantage of a small "lift," vertical component, while its horizontal component, or "drift," which must be overcome by the horizontal component of the propeller thrust, is insignificant. This after plane can be quite small as it has such a long arm, and its advantages well outweigh its disadvantage. The lift of R_W, R_F, and R_A, together with the vertical component of T, equal the weight of the vessel, while the horizontal component of T must equal the drift of R_W, R_F, and R_A. The more the

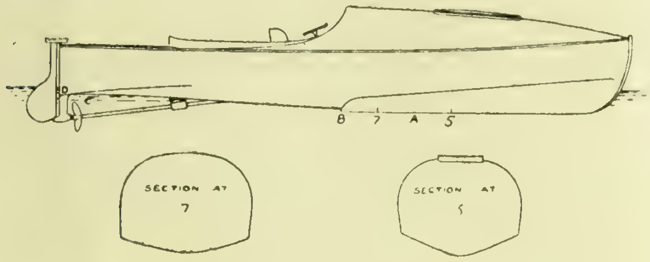

Fig. 1.

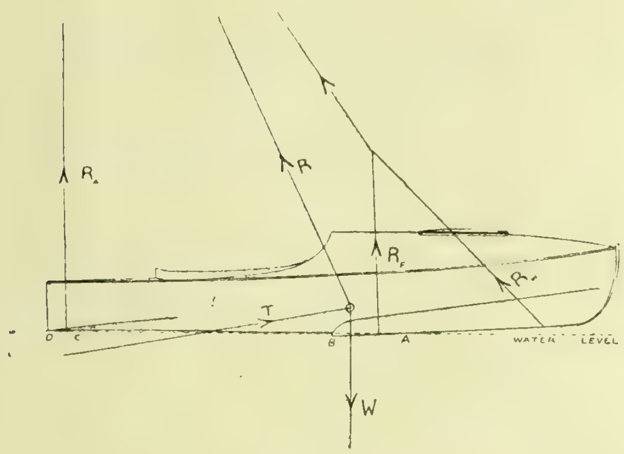

Fig. 2.

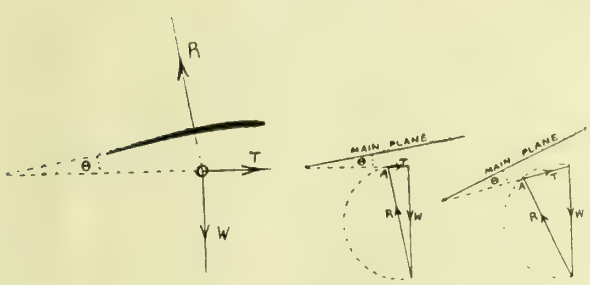

Fig. 3.
"Miranda IV."

fore end emerges from the water, the shorter will become the planes which bear on the water and which give the greatest drift to be overcome by the propeller thrust, so that we may look for increased speed unless the after end should at the same time sink so far as to increase appreciably the drift at that part. This, however, does not seem probable with a propeller shaft set at the angle shown, as the increased vertical component of the propeller thrust should compensate for the loss in lift of the planes. All that has been said applies even if T be no longer central but pass above or below G. In either of these cases, however, we must take into account the shift of the meeting point O relatively to the vessel. It will readily be seen what effect the moving of G forward or aft of an assumed position, or up or down, will have on the pounding.

The next type is in the transition stage between the skimmer and the all-air machine, being designed to fly with its tail always on the surface of the water, and it only leaves the water for an occasional bound into the air, which bound is involuntary, and not one of its natural functions.

"Flying-Fish." — The fuselage of the monoplane (Fig. 4), taken as our example of this type, consists in a water-tight aluminium tank 7ft. 2in. long, 5ft. 7in. wide, and 2ft. deep, with rounded up bow. The sides of the fuselage are carried aft past the hull for 10ft., where they are connected by a cross piece 1ft. wide, which forms the tail. To facilitate the rising of the fore part out of the water, a plane is fitted below the tank part of the body, which plane is tilted up at the fore end so as to ride up through the water. At a moderate speed the fuselage lifts completely out of the water, and the machine glides on the forward plane (A) and the tail. At high speeds the tail only is on the water, all the rest being

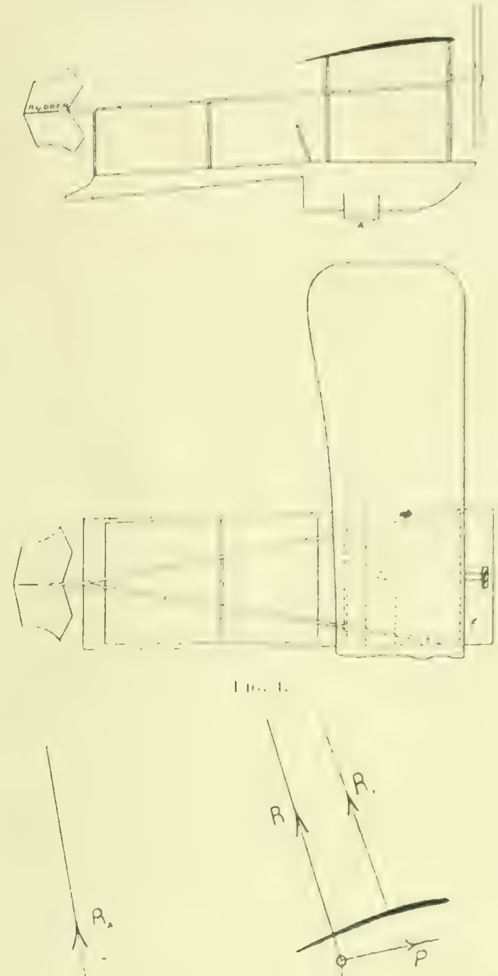

Fig. 4.

Fig. 5.
"Flying Fish."

air-borne. This machine attains a speed of between [illegible] and 70 miles an hour, and is fitted with a single traction screw in front.

When skimming along with its tail on the water (Fig. 5), the "Flying-Fish" is a double-lifting system. The front plane has of necessity a greater angle of attack than the after plane, and the pressure of wind and water respectively on these planes resolve themselves into the resultant pressure R, which must act through the meeting point O of the remaining forces of propeller pull and gravity. The lift of the air or water thrust on the planes, together with the vertical component of the propeller pull, is equal to the weight of the machine; while the horizontal component of the pull of the propeller must equal the drift of the pressures on the planes.

If the pull of the propeller becomes greater than that required to do its portion of the weight lifting, also to overcome the drift, then the forces on the machine will no longer be in equilibrium, but there will be an unbalanced force which will tend to accelerate it in the vertical plane; this will result

in a bound into the air. When the machine is altogether airborne, nearly all the pressure exerted on the after plane has been removed, as now water no longer acts there, only air. The result is that, while R_F remains the same, R_A almost vanishes, causing R to swing forward so that it no longer passes through O. The machine is now no longer in equilibrium under the action of the forces, and a couple is generated tending to overturn the machine backwards. If the machine be inherently longitudinally stable, she will trim by the stern until the moving of the point O forward along the line of action of the propeller pull, together with the travelling aft of the centre of pressure due to the increased angle of attack, again causes R to act through O.

If the machine does not readily assume the new position of equilibrium, the horizontal rudder must be brought into play. When the machine was skimming this rudder was neutral, that is, it had a grazing incidence to the relative wind, and had, therefore, no normal thrust on it. Now, however, it must play its part in the equilibrium of the system, and must be inclined so as to present a face to the wind, which will then exert the lifting force on that part necessary for the restoration of equilibrium. The increase in propeller pull means a bigger vertical component, which would continue to lift the machine were it not for the loss in lift of the after plane, due to the defect of air over water pressure. Again, the increased propeller pull gives rise to a greater horizontal component available for overcoming the drift, and as, at the same time, the latter is lessened by the reduction of drift on the after plane, the machine bounds forward till the loss in lift brings her again on the water.

If the machine be inherently longitudinally stable when flying horizontally in the air, then the critical time as regards stability is when rising from the water, as then the stability falls off as the angle to the horizontal increases; no fear need be felt when alighting, as, the above condition being fulfilled, the machine increases in stability as it descends from the horizontal position.

In what has been said above, the following assumptions have been made. The head resistance has been neglected, that is, resistance due to the wind pressure on the machine, engine, and pilot, and under this heading has also been included the effects of skin friction on the planes. The effect of the concavity of the planes has also been neglected. This results in an alteration in the direction of the resultant pressure, also in the position of the centre of pressure. If, when the angle of attack diminishes the centre of pressure moves forward towards a limiting position, as in the case of flat planes, then there is a loss in stability due to cambering the planes. If, as the angle of attack diminishes, the centre of pressure moves aft, then there is a gain in stability due to adopting camber. Eiffel has shown experimentally that in cambered planes the centre of pressure *does* move aft as the angle of attack diminishes.

The last type chosen for consideration is a machine which is designed to rise from and alight on the water, but it is otherwise purely an air machine, doing long-sustained flights in that medium. As an example of this class of machine, we take the Donnet-Lévêque hydro-aeroplane, which has proved a great success, and is nearer the naval architect's heart than hydro-aeroplanes whose only claim to the additional title consists in small floats being fitted to an ordinary air machine, instead of the usual wheels and skids which enable the aeroplane to rise from and alight on the ground. The single float of the Donnet-Lévêque makes the machine more seaworthy than the multi-float system used in other hydro-aeroplanes, which is good only when the surface of the water is smooth. The hull is divided into several water-tight compartments, which adds to the seaworthiness of the machine. This hydro-aeroplane attains the speed of 70 miles an hour, which is remarkable, as its plane area is comparatively small—183 sq. ft.

(To be continued.)

The British Chamber of Commerce in Paris.—The offices of the British Chamber of Commerce in Paris have been transferred from 17, Boulevard de la Madeleine, to 9, Rue des Pyramides, Paris. This change has been rendered necessary by the rapid extension of the Chamber's work.

INDUSTRIAL AND TRADE NOTES.

Electrical Exhibition at Glasgow.—An electrical exhibition is to be held at Zoo Buildings, New City Road, Glasgow, from October 23rd to November 15th next. Applications for space and full particulars should be addressed to the Manager, 38, Bath Street, Glasgow.

Trade Marks in Japan.—H.M. Commercial Attaché at Yokohama has been informed by the Director of the Japanese Patent Bureau that, in future, trade marks consisting of letters of the alphabet or numerals within ordinary squares, circles, &c., will not, as a general rule, be registered. This decision has been come to because letters of the alphabet and numerals are commonly used by merchants to indicate the quality of the articles, and are therefore not sufficiently distinctive or conspicuous for trade marks. Exceptions may be made in cases where they have a special meaning or are very effective from long use in distinguishing the merchandise.

Geared Turbine Channel Steamer.—Messrs. William Denny and Bros., Dumbarton, launched on Saturday last the steamer "Paris," which they have built for the English Channel service of the London, Brighton, and South Coast Railway. The new vessel, which will develop a high rate of speed, has several noteworthy features, both in hull and machinery. Her principal dimensions are: Length between perpendiculars, 300ft. 6in.; breadth, moulded, 35ft. 6in.; and depth, moulded, 23ft. 3in. The features of the machinery are the application of Parsons gearing to the turbines and the installation of water-tube boilers. The machinery will consist of two independent sets of Parsons compound steam turbines, each set driving a single shaft through gearing.

Tenders for Canadian Contracts.—The Canadian Chamber of Commerce in London has for some time been endeavouring to impress upon local authorities in Canada the advisability of giving such notice of their requirements for public works and municipal and other supplies as will enable British manufacturers to compete as far as time is concerned with their more favourably geographically situated competitors. A number of municipalities and other purchasing bodies in Canada have now arranged to furnish the Chamber with early notice of any appropriation which may be made for constructional and other purposes where it is practicable for the British manufacturer to compete. Copies of tender forms and specifications have also been promised to arrive in London in such time as to enable tenderers on this side to lodge their completed forms in time to receive consideration. The Chamber, whose address is in Northumberland Avenue, W.C., are now prepared to receive the names of any British manufacturers who are desirous of competing for Canadian trade and who would be glad to receive early notification of Canadian requirements in their particular line of business. Upon receipt of such names the Chamber will arrange such channel of communication as would appear to be the most practical and effective.

British Shipbuilding.—The shipbuilding returns compiled by Lloyd's Register show that, excluding warships, there were 563 vessels of 2,063,694 tons under construction in the United Kingdom at the close of the quarter ended on March 31st. Of these 518 of 2,055,773 tons were steamers and 45 of 7,921 tons, sailing vessels. The tonnage under construction was nearly 94,000 tons more than that which was on hand at the end of last year, and it exceeded by about 377,000 tons the tonnage which was being built in March, 1912. The present total is the highest recorded in the society's quarterly returns. Of the vessels under construction in the United Kingdom at the end of March, 437 of 1,586,381 tons were under the inspection of the surveyors of Lloyd's Register with a view to classification by the society. In addition, 124 vessels of 525,147 tons were being built abroad under the society's survey. There were thus actually building under the supervision of Lloyd's Register 561 vesels of 2,111,528 tons. The tonnage under construction to the society's class at the end of last December was the largest ever reached up to that time, but those figures are now exceeded by 84,000 tons. The warships under construction in the United Kingdom numbered 85 of 556,311 tons, 14 of 132,190 tons being in royal dockyards and 71 of 424,121 tons in private yards.

Conciliation in Trade Disputes.—The tenth report of the Board of Trade proceedings last year under the Conciliation Act just issued shows that the number of cases in which action was taken by the Department during that period was 73, this number being less than in 1911, a year of very marked industrial disturbance, when 92 cases were dealt with, but higher than in other previous years. These 73 cases did not include appointments made in connection with the revised railway conciliation scheme. Of the principal groups of trades, the metal, engineering, and shipbuilding trades account for the largest number of cases, viz., 19. The building trade accounted for 10. As in previous years, practically all the

cases in this group were cases not involving a stoppage of work, and joint application was made in every case. The transport industry showed the largest decrease as compared with 1911. The number of cases in this group was, however, considerably above the average of previous years. Of the 12 cases, five involved a stoppage of work. In 1911 there were 21 cases, 18 of which involved a stoppage. The total number of voluntary conciliation boards and standing joint committees in existence at the end of 1912, so far as known to the Department, was 297 (of which 282 were boards dealing with particular trades and 15 district and general boards), including those regarded both under the Conciliation Act and those not so regarded.

Extension of the Birmingham Electricity Undertaking.—The Electric Supply Committee of the Birmingham City Council, at a meeting held on the 9th inst., arrived at a final decision with respect to the proposal to construct a new electricity generating station at Nechells, and lay down plant with a capacity of 100,000 kw. The total cost of this extension will be approximately a million pounds, and when it is finished the station will be one of the largest in the country. It is not proposed, however, to complete the whole of the work forthwith, but to carry it out in sections as the development of the undertaking warrants the extension. At the outset the committee will erect buildings and lay down plant with a capacity of 25,000 kw. at a cost of £250,000. This portion of the work alone will last three or four years; but it is hoped to have the building ready and install plant with a capacity of 15,000 kw. for use by the autumn of 1915. Then in future years the extensions will be continued as required. While this scheme was agreed upon generally four months ago, the committee have since been engaged on certain details. The most important question was the advisability of substituting gas engines for steam turbines for driving the electrical generators. This matter required the most serious consideration. The fullest enquiries were made into the subject, and the committee agreed, on the report of the engineer, to have steam turbines, as they were satisfied steam turbines would be preferable in all the circumstances to gas engines. The committee will now embody their scheme in their next report, and recommend the City Council to approve it.

Electricity Supply for the Potteries.—The new municipal electricity scheme for the Potteries, which has just been completed at a cost of £60,000, was formally inaugurated on the 10th inst., when the new power station in Park Road, Hanley, was opened. Two years ago the Electricity Committee were faced with the necessity of making extensions of their plant in order to cope with the increasing demand for current. There are four stations in the federated area, at Hanley, Stoke, Longton, and Burslem. Combination was not possible in any simple scheme of extension, as the stations were all laid down with separate systems of mains. Instead of extending the existing systems by the addition of plant, the committee, acting under the advice of Mr. C. H. Yeaman, the borough electrical engineer, decided to install a new system, which would be capable, not only of supplying the additional power required, but which would also provide for large consumers in any part of the area. The new plant consists of two 1,500 kw. turbo-generating sets, together with the necessary boilers and accessories. The intention is to use the existing direct-current plant at Burslem and Stoke, and the alternating-current single phase plant at the old Hanley Works so long as it is economical to do so, and to supplement it with power in bulk from the new power station. In order that this may be done, the four old stations have been fitted with rotary or motor converters for the direct current system, and with motor generators for the alternating-current system. In this way it is considered that during heavy loads the local steam plant will assist the new power station, and on light loads the supply can, if found desirable, be taken in bulk from the new station.

The Ghent International Exhibition.—Now that the final arrangements of the British Section are complete, it is possible to give some general idea of how Great Britain is to be represented at the International Exhibition that opens at Ghent at the end of this month. The British Pavilion, which, as has already been stated, stands on the left side of the Court of Honour, facing the French Pavilion, is a large, low building, approximately 130 yards square, divided into a Machinery Hall and four surrounding galleries, where exhibits by a number of Government Departments, exhibits of British Pottery and of Arts and Crafts, and a Library of British trade newspapers will be housed. The industries of Ghent are very largely textile weaving and the manufacture of machinery, and have earned for the town the title of "The Manchester of Belgium," containing, as it does, more than a million spindles for cotton, nearly half a million spindles for linen and jute, and about 50,000 looms. In addition, steam engines, representing about 95,000 h.p., are manufactured there yearly. These considerations have caused the Board of Trade to select machinery as the central feature of the British display. In addition to a large display of machine tools, practically every type of machine used for spinning and weaving will be shown at work, and it will be possible to trace the various processes from the moment that the bale of raw material is opened to the moment the finished fabric leaves the machine. Very interesting displays are to be made by several great English railways, notably by the Great Central Railway. It was originally intended that the new monster engine, the "Sir Sam Fay," built by the company should be sent over to Ghent, but it was found that it could not be spared so long a period. The largest display in the Government Galleries will be that of the Post office, which will include examples of the various instruments used by the Department for the rapid dispatch of telegrams, and a working model of an overhead line. The exhibit of the National Physical Laboratory will illustrate the work done by that Department in elucidating the problems of flight, and show, among other things, how the air currents playing upon an aeroplane are photographed. The work which this Department is doing is practically unknown to the public, though fully appreciated by manufacturers of aeroplanes, who send models and actual parts to be tested for air-resistance. The exhibit of trade and technical journals, which will be shown in a library opening out of the Arts and Crafts Section, and specially designed and decorated by Mr. Frank Brangwyn, A.R.A., is a new departure in British exhibits, and should prove the means of bringing the advertisements of British manufacturers before continental buyers. By the work of the Exhibitions Branch the British manufacturer is relieved of much of the trouble and cost of exhibiting his goods, for the whole work of organisation is undertaken by the Department. Until the Exhibitions Branch was founded the exhibitor was obliged to make his own arrangements for the decoration of his stand, the laying of foundations for his machinery, the storing of his packing cases, and for much similar work, all of which involved expenditure of both time and money. This work is now all undertaken for him, and even when it is necessary for him to pay for any part of it, he is given the benefit of the special rates which the Department has secured from contractors before the prices are raised on the approach of the opening date.

Boiler Inspection in Canada.—Boiler inspection standards and regulations will be uniform throughout the Canadian provinces, after July 1st, as a result of negotiation between representatives from the different provinces. These regulations provide for the rigid inspection of all boilers, during construction, to see that proper materials and safe methods are employed. The object in making the regulations uniform is to ensure a uniform degree of safety and to enable a certificate, granted in respect to a boiler in one province, to be accepted in any of the others. To carry out the provisions of the Act the province will be divided into districts with a chief inspector and two or three district inspectors. These inspectors will be given ample discretionary power in their work, with authority to insist on a proper standard of efficiency being maintained. Hitherto there has been no such system of inspection. Steam-boat and railway boilers are not included, as these are dealt with in a separate Act. Once a boiler is inspected and installed it passes under the jurisdiction of the inspectors under the Factories Act. But where an old boiler is resold that has not been examined within one year of the time of sale, it may not be moved and applied to new work without a further inspection.

Large Turbo Generators with Speed-reduction Gears.—The two largest direct-current generators yet built have recently been completed for the Cleveland (Ohio) Electric Illuminating Company. Each of these is a 3,750 kw. 275-volt 180 revs. per minute shunt-wound machine driven by a Parsons-type steam turbine through Westinghouse reduction gears having a 10:1 ratio. The gear in the reduction mechanism is 100in. diam. with 259 helical teeth. The pinion has 26 teeth, giving a ratio of 26 to 259 and introducing the so-called "hunting tooth" to prevent frequent recurrence of contact between the same pair of teeth. The full rated load of the gear is 5,350 b.h.p., and, on account of overloads, this has been increased to 6,000 b.h.p. without indications of distress. The generator is 21ft. 4in. diam., across the frame-feet base, and it stands 14ft. 2in. above the floor. The entire unit is 37ft. 2in. long, and this length is divided between the generator, gear, and turbine as 10ft. 1in., 12ft. 5in., and 14ft. 8in., respectively. The turbine and gear were made by the Westinghouse Machine Company, and the generator by the Westinghouse Electric and Manufacturing Company, Pittsburgh.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Systems for starting internal combustion engines. Kettering. 28903.

1912.

Carburetters. Drayton & Woodroffe. 4138.
Change speed gearing. Peterson. 7078.
Carburetters for internal combustion engines. Cronan. 7113.
Carburetters for internal-combustion engines. Cox. 7171.
Variable gearing. Pettingill. 7415.
Carburetters for internal combustion engines. Halfin & Wax. 7575.
Apparatus for forcing viscous fluids. Dewrance. 7682.
Gas producers. Matlack. 7712.
Carburetters for internal combustion engines. Muntz. 7873.
Water-lever indicators or gauges for steam boilers. Lloyd and Davies. 7890.
Elastic fluid turbines. Churchill Shann. 7905.
Welding. Kennedy, and British Arc Welding Company. 8987.
Fuel injecting devices for internal combustion engines. Ohlsson. 9535.
Furnace grates. Fletcher. 9555.
Rotary pumps and blowers. Robertson. 11064.
Vices. Farmer. 13324.
Lubricating systems for hot air engines. Model Engineering Company, and Wight. 13429.
Annealing furnaces. John Summers & Sons, Ltd., and Smith. 13513.
Furnaces. Krueger. 13670.
Shaft packing. British Thomson-Houston Company. 14497.
Fuel injection devices for internal-combustion engines. Schneider. 14662.
Delaying devices or dash pots. British Thomson Houston Company. 15070.
Tools employed in the boring of artesian wells. Whatley, Whatley, and Whatley. 15907.
Apparatus for actuating rods for boring artesian wells. Whatley, Whatley, & Whatley. 15908.
Regenerative open-hearth furnaces. Rehmann. 17131.
Apparatus for the better utilisation of heat in fire tube boilers. Duschinski. 18573.
Engine starting mechanism. Gilbert. 19917.
Flying machines. O'Bryan. 20093.
Speed-control apparatus for motor cars. Evans. 20730.
Regulating devices for pumps. British Thomson Houston Company. 21103.
Compressed-air starting device for motors. Jorgensen. 21814.
Airships. Wulffing, Smith, & Aerial Transit, Ltd. 23066.
Fuel calorimeters. Pullen. 24196.
Manometers or pressure gauges. Michaux & Quimfe. 24489.
Bedplates for machinery. British Anti Vibration and Noise Company. 25436.
Ore crushers. Wall. 25471.
Shaft couplings. Hendershot. 28829.
Starting systems for the engines of automobiles. Kettering. 29071.

1913.

Rock drills. Rayner. 772.
Boiler tube cleaners. Imray. 1089.
Screw propellers. Brunner. 2094.

ELECTRICAL, 1911.

Electrical distribution systems. British Thomson Houston Company, and Wedmore. 28868.

1912.

Control of electric motors for electrically operated driving systems. Crompton & Co., Macfarlane, and Burge. 4995.
Method of and apparatus for utilising transformed and primary currents. Dubilier. 6909.
Relays for electric control systems. British Thomson Houston Company. 7014.
Telephone systems. Mellinger. 7100.
Electric and automatic control of engines, dynamos, and batteries. Sunderland & Pillinger. 7375.
Telephone apparatus. Grissinger. 7482.
Brush holders for dynamos. Akt. Ges. Brown, Boveri, et Cie. 7577.
Apparatus for electrically recording the amount of coal supplied to steam generators. Whitie & Langley. 7885.
Electric motor control systems. British Thomson-Houston Company. 8611.
Corrugated secondary battery box. Clark. 10766.
Telephones. Lagus. 11578.
Telegraph apparatus. Pope. 11605.
Securing electrical contact with, and continuity of, the wire armouring on electric cables where the cables are joined together, or connected to apparatus. Hepburn. 13171.
Electrodes for arc lamps. British Thomson Houston Company. 13375.
Electrical switches. Kling & Horton. 16229.
Method for producing electric oscillations or alternating currents. Thompson. 16827.
Contact box for connecting electric motors to the mains. Wintsch. 18992.
Electric motor starters and controllers. Moffett & Rosher. 20113.
Electro-magnetic clutches. "Vulkan" Maschinenfabriks Akt.-Ges. 20922.
Automatic thermic cut out for electric lighting and power transmission circuits. Tasso. 21540.
High-tension electrometers. Bauer. 25101.
Ignition systems. Kettering. 29091.

1913.

Telephone repeater circuits. Grissinger. 2929.
Telephone lines. Grissinger. 2931.
Telephone receivers. Grissinger. 3587.
Telephone sub-station circuits. Grissinger. 3786.

METAL QUOTATIONS.

TUESDAY, APRIL 15TH.

Aluminium ingot	95/- per cwt.
,, wire, according to sizes, &c. ......from	112/- ,,
,, sheets ,, ,, ... ,,	120/- ,,
Antimony ....£31/-/- to	£33/-/- per ton.
Brass, rolled	8¼d. per lb.
,, tubes (brazed)	10½d. ,,
,, ,, (solid drawn)	9d. ,,
,, ,, wire	8¾d. ,,
Copper, Standard	£69/15/- per ton.
Iron, Cleveland	66/1½ ,,
,, Scotch	72/1½ ,,
Lead, English	£19/-/- ,,
,, Foreign (soft)	£18/17/6 ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/10/- per bottle.
Silver	27 3/16d. per oz.
Spelter	£25/7/6 per ton.
Tin, block	£228/-/- ,,
Tin plates	14/- ,,
Zinc sheets (Silesian)	£28/10/- ,,
,, (Stettin; Vieille Montagne)	£28/12/6 ,,

The Institution of Electrical Engineers: Paris Meeting.—The Council have accepted an invitation from the Société Internationale des Electriciens to a joint meeting to take place in Paris from May 21st to 24th next. Members will leave London (Victoria Station, South-eastern and Chatham Railway) at 11 a.m., on May 20th, and will arrive in Paris at 6.45 p.m. On the Wednesday morning the opening meeting will be held at the Conservatoire des Arts et Métiers, when a discussion on the electrification of railways will take place. In the afternoon visits will be paid to the electrical stations of the Electricité de St. Denis and of the Triphasé at Asnières, and in the evening there will be a reception and banquet at the Palais d'Orsay by invitation of the Société Internationale des Electriciens. The morning of Thursday will be devoted to a discussion on long-distance transmission of electrical energy by (*a*) continuous-current, Thury system (paper by Mr. J. S. Highfield); (*b*) three-phase current (paper by M. Maurice Leblanc). In the afternoon there will be a reception by M. Eiffel at the highest platform of the Eiffel Tower, when the wireless installation will be inspected. On the Friday morning the discussion on the papers previously read will be resumed, and the remainder of the day will be spent in visits to places of interest in the neighbourhood. Two papers are down for reading on the Saturday morning, one by M. Claude on "Lighting by Means of Vapour Tube Lamps" (illustrated by experiments), and the other by Commandant Ferrié on "Wireless Telegraphy." In the afternoon an excursion has been arranged to Versailles, and afterwards a visit to the Aerodrome at Buc to witness an exhibition of aeroplane flying.

The Mechanical Engineer.

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Edited by WILLIAM H. FOWLER Wh. Sc., M.Inst.C.E.

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Cheques and Postal Orders should be made payable to the Scientific Publishing Company, and forwarded to our Manchester Office, 53, New Bailey Street.

Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

The "Aquitania."

On Monday last the Cunard liner "Aquitania" was launched from the yard of Messrs. John Brown & Co., Ltd., Clydebank. She is the largest British ship afloat, and but little smaller than the German Hamburg-Amerika liner "Imperator," which vessel, however, she will exceed in speed by about a knot. The launch of a great liner, especially one which in some respects marks the highest achievement in shipbuilding, naturally causes one to survey the progress made in the past. It is, perhaps, not wise to turn one's glance backward too often. Forward is the goal. Still, if one's survey of the past encourages fresh efforts, instead of filling one with a vague longing for the simpler life that is left behind, it can only do good.

It is difficult for us to realise the ships of the ancients, propelled mainly by oars and for the most part undecked, seldom exceeding 100ft. or 140ft. long over all, and 10ft. or 14ft. beam, yet in such vessels Rome and Carthage fought one another, and the Phœnicians traded with the whole of the known world, making voyages out into the Atlantic and across the stormy Bay of Biscay to England. The Vikings invaded Britain in open boats about 70ft. long, propelled by oars, and a sail if the wind was fair. It was almost certainly in one of these frail craft that the Vikings crossed the Atlantic to Iceland for the first time in 874, afterwards going westward to Greenland, and, so it is believed, about the year 1000, a party of them under Eric the Red found their way across to the American continent. There is some uncertainty as to the voyages of Eric, but none as to the famous voyage across the Atlantic which Columbus made in 1492 with three small ships two of them only partly decked, and his flagship, the "Santa Maria," a vessel less than 130ft. long over all by 26ft. wide. This first formal Atlantic passage occupied 70 days from land to land. Cabot made the first Atlantic passage from England in 1497 in a vessel much smaller than the "Santa Maria," and in 1577 Drake left these shores on his

famous voyage round the world with a fleet of five vessels, the smallest of 15 tons. Such were the craft in which our forefathers fearlessly set out to face the terrors of an unknown world, and with the certainty of having to undergo hardships undreamed of in these days of steam power and good food.

There are still people alive who crossed the Atlantic in sailing ships, for although the first steamer, the "Charlotte Dundas," existed in 1802, it was not until the "Savannah" crossed from America to Liverpool with steam up for a portion of the voyage in 1819 that steam was used on the Atlantic passage, and it was not until 1838 that a ship crossed the Atlantic with steam up for the whole voyage. That year marked the entry of the Atlantic liner as we know it to-day, no less than four ships making the passage, and all from this country. The first was the "Sirius," a wooden paddle-steamer, 208ft. long over all, with a speed of under eight knots. The "Great Western," which arrived at New York only one day after the "Sirius," and was 236ft. long, and rather faster than the latter, was the first steamship built for the Atlantic trade. It is interesting to compare her 236ft. with the 902ft. total length of the "Aquitania," her displacement of about 3,000 tons with the 47,000 tons of the new liner, and her 2-cylinder simple engines of 750 h.p. (this being more than double that of the "Sirius") with the 60,000 h.p. turbines of the Cunarder. Even these figures, striking as they are in their comparison, fail to convey the full measure of the advance which the modern Atlantic liner of to-day marks over the first of her type. The first Atlantic liner to be built of iron was the Cunard paddle-steamer "Persia" in 1856. She was followed late in 1858 by the "Great Eastern," a tremendous ship in her day and embodying many innovations of construction which were afterwards adopted as standard practice. She was 692 feet long over all by 83 feet wide, and was propelled by paddles and a screw. She was too big for her day, and too feeble in engine power for her size, so that it was over 40 years before a ship so long was built. Meanwhile, progress was being made steadily. Compound engines became general in the sixties and triple engines towards the eighties. The paddle gave way to the screw in the sixties, the first Cunard screw steamer being the "China," built in 1862; and in the seventies steel began gradually to displace iron on the same grounds that the latter had displaced wood—saving in weight and greater satisfaction generally.

Steam turbines were first used on the Atlantic by the Allan liners "Virginian" and "Victorian" in 1905. These vessels are of comparatively moderate size and speed, being 520ft. long by 60ft. wide, and of 12,000 h.p. In the same year the Cunard Company built the "Carmania," 650ft. long between perpendiculars, and having turbines of 22,000 h.p. The "Lusitania" and "Mauretania" followed with quadruple instead of triple screws, and with turbines of 68,000 h.p. These ships, launched in 1906, were 785ft. long over all by 87ft. 6in. beam, and were the largest in existence at the time. Their speed of 25 knots has not yet been exceeded, the "Aquitania" being expected to average 23½ knots only, and the "Imperator" and the "Olympic" 22½ knots. Thus far have we progressed, but the end is not in sight.

London University.

THE Royal Commission appointed to report on the London University has issued a unanimous report which is of more than merely executive interest. London is typically English in its individualism and in university matters this individuality has not taken sufficient account of the need for concentration and unification in higher education; with the result that even to-day, in spite of considerable improvement in recent years, London University is not such as Englishmen can feel proud of. London is the capital city of the Empire, and, with its huge population and enormous wealth, ought to maintain a university of corresponding rank. Instead, the London University consists of two fairly creditable colleges, to which are more or less loosely connected a number of other educational institutions, and it gives degrees on two distinct bases, one to resident students and the other to externals, who merely sit for examination. As a training ground for men of affairs, London University does not compare with our older universities; and with, perhaps, the exception of medicine, for the study of which London hospitals provide splendid opportunities, our provincial universities, both old and new, would challenge it in every subject.

We do not make the above remarks with any desire to belittle the metropolitan university, but to show how complex the problem of London's higher education is and at the same time to urge that the greatest city of the world simply cannot afford, as a matter of individual interest, of national business and of Imperial pride, to be content with anything but the best in higher education. With the detail recommendations of the Royal Commission for strengthening the London University by the inclusion of certain other institutions, and various changes in constitution and organisation we do not propose to deal, but the subject of external degrees calls for some comment. The facilities for granting degrees to people who merely pay a fee and pass an examination without, in most cases, attending the university courses of study, are proposed to be only slightly restricted at present, but there seems a likelihood that the restrictions will be gradually increased until, finally, degrees will only be granted to resident students. The objection to the external degree is that it is merely a matter of examination and that examinations are a very poor test of the character and quality of a man. It is true that the same test is applied to the internal or resident student, but in his case it is known without any examination that he has studied in the regular courses for three or more years. A student may do this and emerge little more than a bookish crammer, but in general he enters into the corporate life of the place and thereby imbibes some of its living spirit and acquires the seeds of that comprehension of men and things which is of such great importance in the higher walks of life. One may read football reports until every move of the game is familiar, but one can only become a footballer by practice on the field. In the same way, to establish a claim to stand above one's fellows—which should be the meaning of a degree—one must justify it on a more practical field than an examination paper. At the same time, in a practical world one must make allowances for those who are not fortunate enough to secure attendance at a university. Examinations are defective, but they at least serve to measure something of some value and, above all, they afford many persons an incentive to study and self-discipline which not only adds to their knowledge, but strengthens and refines the quality of the individual. It is fitting that such effort should be recognised by some form of degree, but such degree should be clearly distinguished from that granted to resident students.

West of Scotland Iron and Steel Institute.—The 21st annual meeting of this Institute was held at Glasgow on the 18th inst. The annual report stated that there was a satisfactory increase in membership, bringing the total up to 450. The report was adopted.

THE LATE MR. HENRY HILLER.

We regret to announce the death of Mr. Henry Hiller, which took place in Manchester on April 9th, at the age of 79. He was born and educated in Sheffield, and served his apprenticeship with the engineering firm of Messrs. Walker, Eaton, & Co. There were very limited facilities for any theoretical education in Sheffield at that time, and Mr. Hiller frequently used to contrast the wealth of evening classes now offered to young engineers with the difficulty of the situation in which he and others found themselves in those days, when the most they could obtain was a class in mechanical drawing. After his apprenticeship, Mr. Hiller worked in the Manchester district as a fitter at the works of Messrs. Sharp, Roberts, & Co., and also at Gorton Tank. He was subsequently appointed to be assistant to the chief engineer of the Manchester Steam Users' Association. He spent some time in that service, and in 1864 was appointed chief inspector and afterwards chief engineer of the National Boiler Insurance Company, of Manchester. The National Company, which is now one of the leading institutions in the particular branch of engineering devoted to inspection and insurance, was then in its early days, and the whole of Mr. Hiller's energies were occupied in the development of the company, both on the engineering and the commercial side. From the very first Mr. Hiller kept before himself the principle of prevention of explosion by careful and efficient inspection, and during the whole of his connection with the National Company he developed the work of the organisation on these lines.

In the early days the general nature of the work involved was in the first place convincing boiler owners of the necessity of having their boilers regularly inspected, and those persons responsible for inspecting and insurance organisations had to spend very much of their time in missionary work—endeavouring to convince users of steam power of the soundness and necessity of what is accepted to-day as a self-evident principle. The period of Mr. Hiller's work was one of considerable change in boiler construction and attention, and he took a great part in the work of improving boiler design, which in this country is attributable in a large degree to the work of the insurance companies. In the early days of the period referred to the boilers in use included long externally-fired egg-ended boilers commonly put down in ironworks, a large number of shorter externally-fired boilers at collieries and similar places, together with Cornish and Lancashire boilers. The pressures were low, about 30lbs. to 60lbs. per square inch; the materials of construction were iron plates having generally a low ductility and tensile strength; the rivet holes were punched, and the plates were bent from the flat after the holes had been made. Hand riveting was generally in use. At the end of the period in question pressures had increased to 100lbs. to 150lbs. per square inch; materials had been greatly improved by the introduction of mild steel plates; methods of construction had advanced by the adoption of making the boilers of one ring in each plate, the rivet holes being drilled from the solid; types of boilers had changed, the old externally-fired egg-ended boiler having become obsolete, and the Lancashire and similar types having been much improved in detail; also the high-pressure water-tube boiler had firmly established itself.

The history of the National Boiler Insurance Company, with which Mr. Hiller was engaged, is bound up and identified to a great extent with the changes which took place, and there is no doubt that a great part of the credit for the advance in construction, care, and inspection which have shown themselves by a great reduction in loss of life and damage due to boiler explosions, are attributable to the work which was done by Mr. Hiller and other engineers in similar positions. It is not commonly realised in how great a degree the advances in the past in the development of steam power have been bound up with the development of the boiler insurance companies. On the staff of the National Company, with which Mr. Hiller was associated, and which is now under the direction of his son, Mr. Edward G. Hiller, there is over 300 persons, and the number of engineers employed in inspecting, supervising, and the like is over 100. In addition to the work directly connected with the inspection of steam boilers and the like, Mr. Henry Hiller was of an ingenious mechanical turn of mind, and took out a number of patents, referring principally to fusible plugs, safety valves, &c., which proved very successful.

DEVELOPMENTS OF THE ROE PUDDLING PROCESS.

The developments that have taken place in the Roe process of puddling were described by Mr. D. E. Roberts at a meeting of the Staffordshire Iron and Steel Institute, held at Dudley on April 5th. Since its first introduction in 1906, the inventor had had to overcome many difficulties to get his process taken up. Eventually the Reading Company, who are the largest makers of wrought iron in America, determined to put down a plant, which had recently been started up. The Reading furnaces are of the oscillating pattern and very large, measuring 26ft. long by nearly 12ft. wide inside. They have made heats well over 6,000lbs. in weight. The gain in weight sometimes reaches 11 per cent. The following are actual figures:—

Pig charged	....	5,300lbs.	Billets	...	5,855lbs.
,, ,,	....	5,450lbs.	,,	...	6,080lbs.
,, ,,	....	5,150lbs.	,,	...	5,766lbs.

This is due partly to iron reduced from the oxide in the cinder, and also to the absence of any waste by surface oxidation after the process is complete, for the ball is discharged into the squeezer immediately it is made. The plant consists

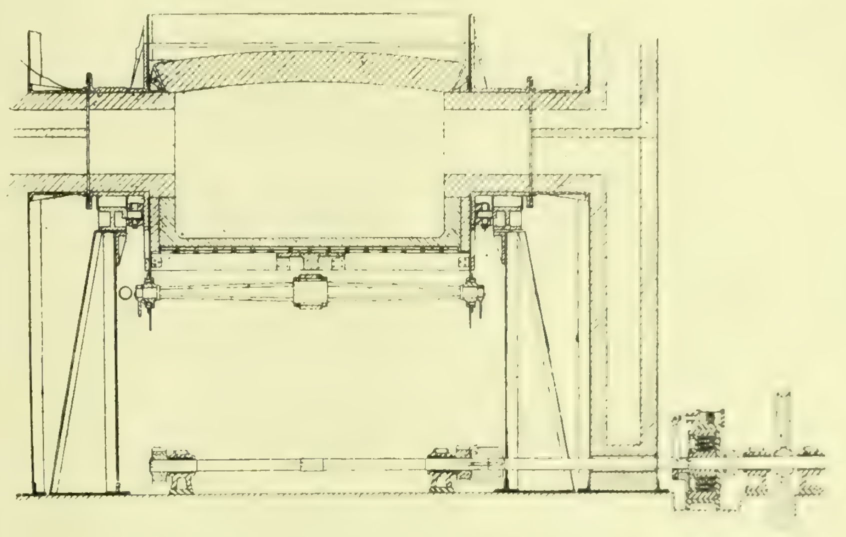


Fig. 1.—Roe Puddling Machine. Longitudinal Section.

of two furnaces, but has been so designed that it can conveniently be extended to twelve. No. 3 is being proceeded with, and arrangements are also being made to extend the buildings for the accommodation of furnaces Nos. 4, 5, and 6. The furnace bottom, originally a straight line, is now shaped as in Fig. 2. This is done for two reasons: (1) It is found in operation that to keep the bottom clean, about half of it must always remain exposed to the flames, and thus be kept hot; (2) the incline also gives the charge a more rapid start at the beginning of each descent.

First of all, the fettling, which consists of puddle tap cinder in a re-melted condition, is inserted. This melting is done in another small tilting heating furnace close at hand. The puddling furnace is then rocked a few times until this fettling washes well over the bottom, and then the molten charge is put in and operation commences. The conditions of operation being the same exactly as those in an ordinary puddling furnace, a similar kind of cinder is required, and an important point is its proper production and maintenance, both chemically and physically, *i.e.*, the correct amount of silica and oxide of iron. The quantity of fettling necessary is, of course, regulated by the quantity and the quality of

the iron used. The furnace is rocked upon hollow trunnions, and through these trunnions gas and air come in, and combustion takes place. The roof is raised as shown at the centre, to give room for combustion. There are two curved chimneys on each end of the furnace, through which gases escape, and when the rocking proceeds, the gases escape from the chimneys under a large canopy which practically covers the whole furnace, and the heat escaping from the chimneys under this canopy heats the air for combustion in what is called the "recuperator," this air later entering the furnace. The speed of rocking is controlled to fit the conditions as they change during the process. When the iron is molten, the furnace is moved very little and gradually, but as the process begins to develop then the amount and speed of the rocking increases, and eventually, as the iron comes to nature, dries up, and the ball is formed, it develops to the maximum. The proper manipulation of the oscillations enables the entire mass to be uniformly finished, this being assisted by the great width of the bottom. Care, of course, has to be taken that there is no raw iron present when the final massing by impact takes place to form the ball. At the final movement the door at one end of the furnace is opened, and the ball

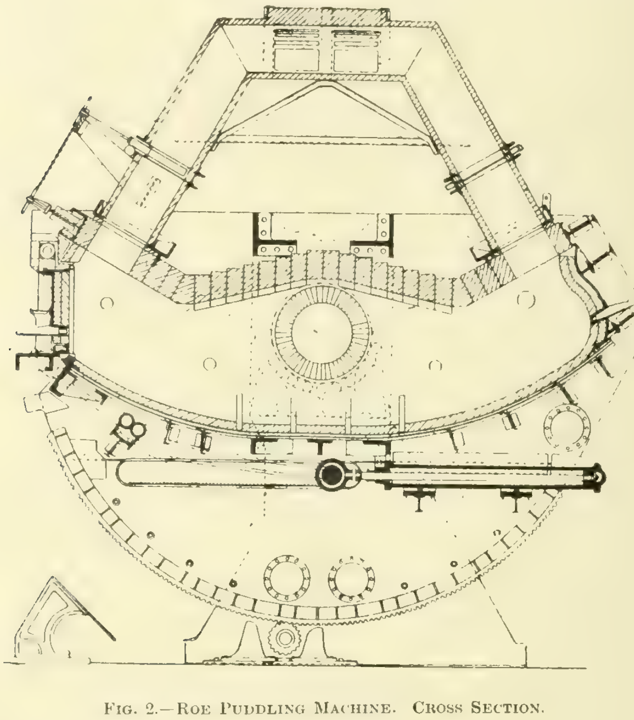


FIG. 2.—ROE PUDDLING MACHINE. CROSS SECTION.

is thrown out into a cradle waiting to receive it. The receiving cradle puts the ball into the hydraulic press, and there it is subjected to heavy pressure all over, and a slab is produced about 28in. wide by about 7in. thick, and about 12ft. 6in. long. All sides of the press for squeezing the block are perforated to allow the cinder to get away.

The furnaces are each capable of turning out a heat approximately once an hour, and although they are called 2½-ton furnaces, yet on a few occasions several heats have amounted to well over this total. Each furnace is good for about 30 tons output per day of 12 hours, and approximately on a reasonable basis of 300 tons a week. Considerable economy from the labour point of view is obtained, as each furnace only requires three men, one puddler and two helpers. Thirty tons a day with three men is equal to ten tons per man, as against the present output of something between 0·6 or 0·7 ton per man per day, a difference of, say, 15 to 1. The slabs can be produced for nearly the same cost as open-hearth ingots of similar weight. It is claimed from actual experience that not only is the product made much cheaper, but that it is improved in character over ordinary puddled iron, due to: (1) More thorough agitation; (2) working on a hot bottom, and consequently greater uniformity of the mass; (3) less likelihood of laminations when the mass is rolled direct; (4) more scientific control of the cinder, and thereby of the character of the product. It is also found that a greater range of pig-iron is made possible for a given product.

The Reading Company take the slab formed in the press, shear it up into short pieces, and roll each piece separately. The author believes that they were led to this system by the fear that possibly in so large a slab the cinder left in the middle might be excessive, but it has been found from very careful examination and tests that the squeezing of the slab clears out the slag in the most uniform manner, so that there is not more of it left in the middle than there is near the surface of the bloom. The author has particularly referred to this point, as it would appear to him that to suit the conditions in the South Staffs. district any producing plant that might be put down, with a mill attached, should be able to turn off in large quantities from the roughing-mill billets, say 4in. or 5in. wide, which could be sheared up into suitable lengths of correct weight, and be distributed throughout the district amongst the numerous finishing mills, and there take the place of the present pile. There is, in the author's opinion, an immense field here for such a producing plant, if only to supply the present demand of these finishing mills. Judging from the present information to hand regarding the process, there is no doubt that such a plant could deliver, to these various mills, billets ready for heating and rolling at a very handsome saving compared with the price at which such mills can now provide themselves with the article piled ready for heating. It will be realised that apart from the saving due to the large units handled, and the great reduction in the labour cost, there are also savings from the far smaller quantity of crops, apart from the fact that the Roe billets suggested are much more easily handled than is the material which at present goes to make up the pile.

The cost of putting down such a plant as this is necessarily an expensive item. A furnace as shown in the illustrations, and alone as it stands, can be put down for between £5,000 and £6,000. Taking into consideration the entire equipment necessary, and embodying two furnaces only, this would work out at approximately £30,000 per furnace. Upon a larger plant, however, which would embody, say, six furnaces, the cost would work out approximately at £20,000 a furnace, and with this plant of half-a-dozen furnaces, assuming that one is always idle, an output of approximately 1,500 tons a week of puddled iron could be obtained.

Explosions in Mines.—The Home Office has just issued the third report from the Explosions in Mines Committee on the influence of incombustible dusts on the inflammation of gaseous mixtures. The conclusion that the Committee have drawn from the experiments is that the presence of suspended incombustible dust in weak gaseous mixtures does not render them more explosive than before. On the contrary, they are of opinion that as heat-absorbing material they render such mixtures less explosive. The introduction of incombustible dust into a mine for the purpose of lessening the danger of coal-dust would not, they remark, even if Abel's contention was correct, introduce a source of danger that was not already present, for whatever the incombustible dust could do in promoting gaseous explosions, coal-dust could do much more effectively. Whatever danger of gaseous explosions might exist already by reason of the presence of coal-dust, it certainly would not be augmented by the addition of incombustible dust. They are, however, of the opinion that incombustible dusts do not have the effect attributed to them by Abel, but have a distinctly contrary effect. They do not therefore apprehend any increase of danger from gas explosions by their introduction into mines. Experiments with incombustible dust were being continued in the large gallery, and they hoped soon to publish an account of them. Having thus found that inert dust had a retarding effect upon the ignition of mixtures of gas and air, it occurred to the Committee to try whether inert dust could stop an explosion of gas and air which had already formed and was in progress. They found this to be the case in a series of preliminary trials. It would, however, be premature to draw conclusions from them until they have been repeated on a larger scale."

QUADRUPLE SCREW TURBINE-DRIVEN CUNARD LINER "AQUITANIA."

Built and Engined by Messrs. John Brown & Co., Ltd., Sheffield and Clydebank.

Bow View of the Vessel on the Stocks.

The "Aquitania," which was launched from the yard of the builders, Messrs. John Brown & Co., Ltd., Clydebank, on Monday last, combines, in her design and construction, the experience and invaluable information deduced from the construction and performance of the "Lusitania" and "Mauretania," and the many other famous ships that have preceded her under the Cunard flag. Each succeeding vessel built for the company during the 73 years of its existence has in one way or another marked an advance on its immediate predecessor. The principal figures of the "Aquitania" are: Length, 901ft.; breadth, 97ft.; depth to boat deck, 92ft. 6in.; gross tonnage, 47,000 tons; speed, 23 knots; accommodation for 3,250 passengers and a crew of nearly 1,000.

The unprecedented weight, length, and other abnormal features of the great ship involved the consideration of unusual conditions, and, like everything else connected with the construction, demanded arrangements being made on a scale of magnitude never before required on the Clyde. In order to lay down the leviathan the whole face of the yard had to be changed. The ground on which the ship was to be built had to be specially prepared and strengthened, piled and cross-piled. Over the cross piles were placed layers of steel plates, then quantities of cement, it being essential that the ground should not yield an inch at any point. New crane systems had to be installed for lifting the heavier materials on to the wider, longer slip. The same berth was used as that upon which the "Lusitania" was built, but owing to the much greater length of the "Aquitania" the preparation of the ground had to be very considerably extended. The berth being in line with the river Cart, which flows into the Clyde almost opposite the yard, enabled the builders in launching the ship to avail themselves of this natural advantage. The new ground was prepared as that for the "Lusitania." The part on which the earlier ship structure had rested required, of course, comparatively little treatment beneath its surface. The blocks were then put down, the keel laid, and the frames erected. In addition to the preparations in the yard the river had to be deepened and widened, and the builders' fitting-out basin at Clydebank has also had to be dredged in order to accommodate the liner during completion.

An important feature in the "Aquitania," as in the "Lusitania" and "Mauretania," is that extending throughout the most vulnerable parts, there is that great desideratum a ship within a ship. In other words, there are two shells

the inner as well as the outer shell, both being watertight. The space between the outer and inner skins averages about 15ft., and at short intervals there are bulkheads dividing this intervening space into relatively small compartments. It will be understood, therefore, that any fracture of the outer shell due to collision will result in the ingress of the sea being limited to a small area at the side of the ship. In addition to this important provision, there are 16 bulkheads extending athwartship from the port to starboard side. It might be thought that this combined system of transverse and longitudinal vertical watertight sub-division was in itself sufficient safeguard against flooding, but further provision has been made by the development of the system of fitting watertight decks which was introduced into the construction of the "Lusitania" and "Mauretania." It will thus be seen that from a point of view of strength the "Aquitania" embodies the main features of the "Lusitania" and "Mauretania," with additions consequent upon increased beam and length. The "Aquitania" will also be fitted with Frahm's anti-rolling tanks, which have proved so successful in the "Laconia." There are altogether eight decks on which passengers are carried. The division of the ship into watertight compartments is much more extensive than is required by any regulations, and exceptional conditions might therefore have been obtainable in connection with the lifeboats, but the Cunard Company, 15 months ago, submitted their plans to the Board of Trade for an installation of lifeboats to accommodate every passenger on board. Two motor lifeboats will also be provided.

The vessel is fitted with four screws driven by steam turbines of 60,000 i.h.p. The turbines, which have been constructed by the builders of the vessel, are arranged to work on the triple-compound system and are located in three engine-rooms, one in each wing and a centre compartment. The wing shaft is driven by a high-pressure turbine, which exhausts into an intermediate-pressure turbine on the starboard wing shaft, the steam flowing thence to a pipe leading into both low-pressure turbines mounted on the inner shafts, the arrangement being such that any of the turbines may be cut out at will in the event of an accident. Some idea of the dimensions of the turbines is afforded by the photos on page 447. The boilers, 21 in number, are of the double-ended marine type, constructed for a working pressure of 195lbs. per square inch, and are each fitted with Howden's system of forced draught. The electrical installation is very complete and comprises four Westinghouse impulse turbines, each driving a 225-volt three-wire direct-current generator of 400 kw. at 1,500 revs. per minute. For emergency purposes a Mirrless-Diesel oil engine, driving a 30 kw Westinghouse generator, will be provided. Close on 200 motors, ranging from 60 b.h.p. to $\frac{1}{4}$ b.h.p., will be installed to meet the varied requirements on board ship. The vessel will be lighted throughout by close on 7,000 electric lamps.

HANDLING HEAVY MACHINE PARTS WITH CRANES.

BY JOHN RIDDELL.

THE handling of heavy machines and parts of machines in a large electrical factory is, of course, a matter of the greatest importance. The apparatus used includes travelling cranes, jib cranes, and other machinery; and, during the ordinary working day, has to deal with weights varying between very wide limits. The different cranes may vary in capacity from, say, 3 tons to 100 tons; and the weights of the pieces which have to be handled may be anything from 100lbs. to 100 tons.

As a general rule, no particular trouble need be expected in handling the larger weights, since, owing to their importance, more care is exercised in making hitches and other preparations. It is from pieces of medium weight and light weight that trouble more often results. The man handling so much of this class of work becomes thoughtless, the slings become chafed and worn, and the chains become crystallised by long use. The last is a frequent cause of trouble. There is a great difference between ropes and slings used for hoisting. In ropes the wear can always be seen by the strands becoming frayed, loose, or cut. A chain, outside of a few bruises, will not show any signs of weakness; although actually it may be full of small cracks which cannot be seen by the naked eye, or it may be much crystallised by long use. A chain under these conditions is rapidly becoming weaker with each lift; until it finally fails.

But whether anyone is hurt or not, there is always a loss to the factory. Sometimes it may only be a rough casting, but very often it is a piece of finished apparatus on which much time and labour have been spent; and worst of all, there is usually urgent need for the apparatus at its destination, and disappointment to follow. Suitable racks should be provided for hanging chains and slings on, and when not in actual use they should be kept on these racks. When not following cranes and making hitches, the followers should be inspecting these slings to detect weaknesses and sorting out the bad ones to have them repaired.

Wire cable slings occupy a very important place in hoisting, and have been found very satisfactory when carefully used. A wire cable sling should never be used singly when hooked by a spliced eye. When the weight is sufficient the cable is liable to untwist, thus allowing the splices to open and slip. Such slings should always be used double, and where sharp corners or rough castings exist the cable should be protected by pads. Another method of protecting the cable is by two loose metal blocks that should be perfectly free to adjust themselves and afford ample protection for the slings so used.

TABLE I.—*Eye Bolts.*

	Inches. A	Inches. B	Inches. C	Safe Load Lbs.
	$\frac{1}{2}$	$1\frac{1}{2}$	$\frac{7}{16}$	1,100
Drop forged steel.	$\frac{9}{16}$	$1\frac{9}{16}$	$\frac{17}{32}$	1,500
	$\frac{5}{8}$	$1\frac{11}{16}$	$\frac{5}{8}$	1,800
	$\frac{3}{4}$	$1\frac{13}{16}$	$\frac{3}{4}$	2,800
	$\frac{7}{8}$	$1\frac{15}{16}$	$\frac{13}{16}$	3,900
	1	$2\frac{1}{16}$	$\frac{15}{16}$	5,100
	$1\frac{1}{4}$	$2\frac{5}{16}$	$1\frac{3}{16}$	8,400
	$1\frac{1}{2}$	$2\frac{9}{16}$	$1\frac{3}{8}$	12,200
	$1\frac{3}{4}$	$3\frac{1}{16}$	$1\frac{1}{2}$	16,500
	2	$3\frac{1}{16}$	$1\frac{5}{8}$	21,800
D.B.G. Iron E.L., 28,000 lbs. per sq. in. welded.	$1\frac{3}{4}$	3	$1\frac{1}{4}$	10,000
	$1\frac{3}{4}$	4	$1\frac{1}{2}$	11,000
	2	5	$1\frac{3}{4}$	14,000
	$2\frac{1}{4}$	6	2	16,000

A = outside diameter of bolt shank; B = inside diameter of eye; C = diameter of stock in eye.

In using slings of any kind, especially rope, care should be taken to see that they are properly laid; *i.e.*, to see that one rope does not lie on top of the other, as this will prevent proper equalisation, putting an undue strain on the outer rope. It very often happens, when a rope sling is used double, that the ends of the rope are passed through the doubled part, as when placed around a casting; and, unless this is done carefully, instead of having the strength of two parts of a rope, as supposed, it can be so slipped around the casting, or other piece being lifted, as to actually only have the strength of one part.

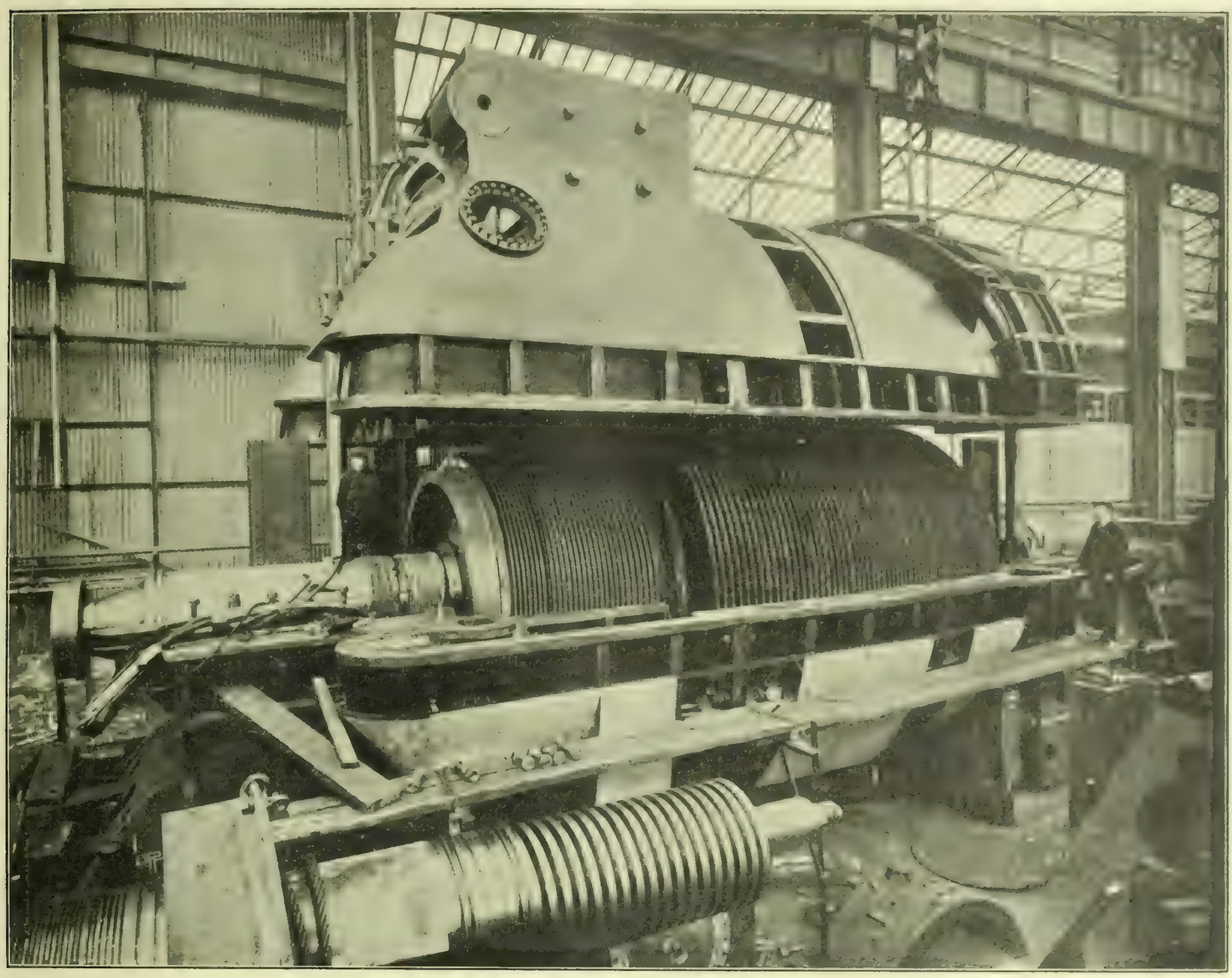
Before lifting heavy loads by means of a crane, the crane brakes should always be tested to see that they are in good condition and will hold. Care must be used when lowering loads to limit the speed, which should not exceed the hoisting speed of the crane for the same load. Particular care must be taken to apply the brakes gradually when bringing the load to rest. The ordinary hoisting speed for a 30-ton motor-operated crane is about 18ft. per minute, and for a 50-ton crane is about 18ft. per minute with the rated load. Stopping the load at such speeds within a distance of $\frac{1}{2}$in. may double the stress on the slings and crane. This point cannot be emphasized too strongly; as, in more than one instance, serious accidents have resulted from the sudden stopping of a crane while the load was being lowered.

When a weight is lifted by two or more slings connected to the crane hook and making an angle with each other, the increase in the stress of the individual slings must be considered. On account of this angle between the two sets of slings the stress on each set is greater than half the total load, and increases very rapidly as the angle between the sling and the work is decreased. An angle of 45° between the sling and the work makes the stress in each sling three-fourths of the total weight, and the collapsing force between the two

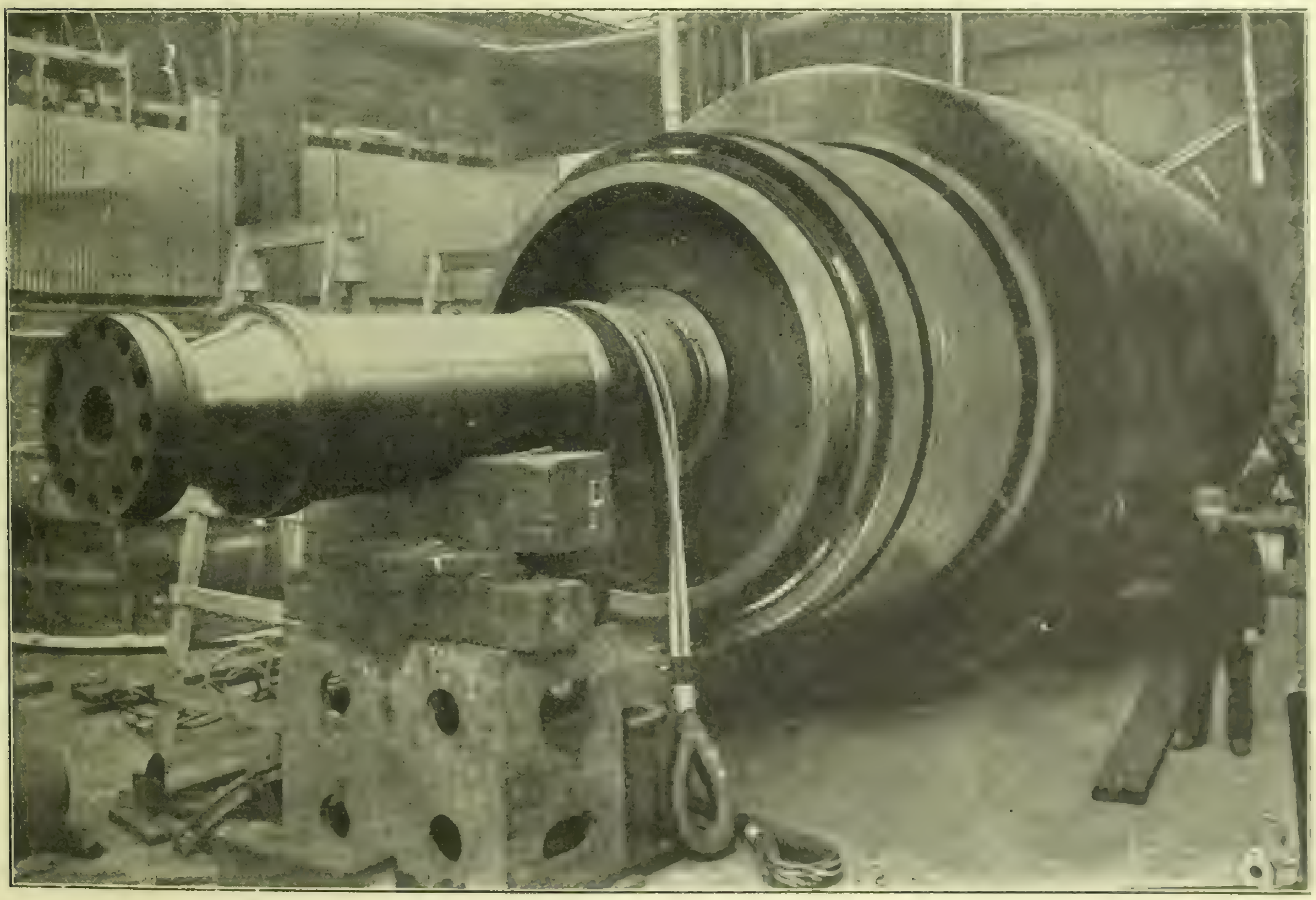
TURBINES OF QUADRUPLE-SCREW CUNARD LINER "AQUITANIA."

Constructed by Messrs. John Brown & Co., Ltd., Sheffield and Clydebank.

(For description see p. 445.)



A Low-pressure Ahead and Astern Turbine, with Upper Casing Raised



Rotor of One of the Two Low-pressure Ahead and Astern Turbines

points of attachment to the work is equal to one-half the weight. This collapsing force acts in a direct line between the two points of attachment. If the work is ring-shaped, it would tend to deform the ring. A spreader of sufficient stiffness should be used between these two points to resist this collapsing force. It will be seen that eyebolts are not suitable for attaching the slings to the work unless a spreader is used to relieve them of this side pull, which would put a heavy bending moment on the shank of the bolt. Reducing the angle between the sling and the work to 30° makes the stress in each sling equal to the total weight, and the collapsing force is also equal to the total weight. Such a small angle should never be used if avoidable.

work to be able to decide on a proper method, and the proper slings or other apparatus to be used. Where he is in doubt as to the weights to be lifted or methods employed, he should seek advice from those qualified to give it. For the guidance of those engaged in handling or lifting pieces it is also suggested and urged that all irregular shaped castings, and in fact, all castings weighing over a ton, should have the gross weight marked in plain figures. It is always safer to overestimate a weight than to underestimate it; and it is always safer to use slings of ample lifting capacity than those about which one is in doubt.

Other defects besides those in lifting apparatus will occasionally be discovered, such as a cracked arm of a flywheel, or other similar piece. If this defect is discovered by the person originally handling the piece, he should call his superior's attention to it immediately upon making such discovery. Those engaged in this important class of work should also have some idea of the strength of materials. They should know how the strains will be set up in such materials, and also know how to apply slings for lifting. They should know that using too small an angle on the slings, as in the case of a field ring, will tend to pull the sides together; and that, in the case of a revolving field where the sling is applied between a pair of arms instead of around adjacent arms, the tendency will be to break out a portion of the ring. These things are all matters of judgment and the importance of appointing proper persons to have charge of this work cannot be urged too strongly. A reduction in the number of crane accidents can only be effected by extreme vigilance. The loss of material in the past has been very great. The suffering to humanity caused by thoughtlessness has been as great. With proper care such accidents can be almost totally avoided.—"General Electric Review."

Table II.—*Safe Loads on Ropes, Chains, and Cables.*

Manila Rope.				Wire Cable.				Chains.			
Diam. of Rope in In.	Safe Load in Tons.			Diam. of Cable in In.	Safe Load in Tons.			Diam. of Chain in In.	Safe Load in Tons.		
	Single Rope.	Two Part.	Four Part.		Single.	Two Part.	Four Part.		Single Chain.	Two Part.	Four Part.
$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	1	2	$3\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{7}{8}$	$1\frac{1}{2}$
$\frac{5}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{5}{8}$	$1\frac{3}{4}$	$3\frac{1}{4}$	$6\frac{1}{2}$	$\frac{3}{8}$	1	$1\frac{3}{4}$	3
$\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{4}$	$1\frac{1}{4}$	$\frac{3}{4}$	$2\frac{1}{2}$	$4\frac{1}{2}$	9	$\frac{1}{2}$	2	$3\frac{1}{2}$	6
$\frac{7}{8}$	$\frac{1}{2}$	1	2	$\frac{7}{8}$	$3\frac{1}{4}$	6	12	$\frac{5}{8}$	3	5	9
1	$\frac{3}{4}$	$1\frac{1}{2}$	$2\frac{1}{2}$	1	4	8	16	$\frac{3}{4}$	5	9	15
$1\frac{1}{4}$	1	2	3	$1\frac{1}{4}$	6	12	24	$\frac{7}{8}$	6	$10\frac{1}{2}$	18
$1\frac{1}{2}$	$1\frac{1}{4}$	$2\frac{1}{2}$	4	$1\frac{1}{2}$	10	19	36	1	8	14	24
$1\frac{3}{4}$	2	4	6	$1\frac{3}{4}$	13	25	48	$1\frac{1}{8}$	11	19	33
2	$2\frac{1}{2}$	5	8	2	16	32	60	$1\frac{1}{4}$	13	23	39
$2\frac{1}{4}$	$3\frac{1}{2}$	$6\frac{1}{2}$	11					$1\frac{1}{2}$	18	32	54
$2\frac{1}{2}$	$4\frac{1}{2}$	8	13								

When it is necessary to use eyebolts for lifting loads, no greater strain should be allowed than given in Table I., which gives the safe load in pounds for bolts up to and including $2\frac{1}{4}$in. diam. It should be noted that the values given are correct only when the pull is in the direction of the axis of the threaded shank, and when the bolt is in good condition.

It should be understood that, to obtain the greatest strength from an eyebolt, it must fit reasonably tight in the hole into which it is screwed, and the pull applied in a line with the axis of the screw. Eyebolts should never be used if considered the least faulty. They should never be painted when used for miscellaneous lifting, as paint is very apt to cover up flaws. They should be tested occasionally by tapping gently with a hammer, but not sufficiently to bend or to otherwise injure them. If it does not impart a good ring, one of two things is the reason. It may fit too loosely in the hole, or there may be a flaw. Where a bolt is to be used for anything like its maximum load it should be screwed in tight with a bar and given a gentle tap with a bar or hammer to see if it imparts a solid feeling. If not, it should not be used.

Table II. gives the safe loads which may be put on manila rope, wire cables, and chains. The first column gives the diameter of the rope or chain, the second column gives the safe load which the rope or chain is to carry singly. In a sling where the strain is carried by two ropes or chains, the loads given in the third column should be used. In a sling where four parts of the rope or chain carry the load, the figures in the fourth column should be used. Figures are in tons of 2,000lbs. each. The loads for manila rope should be used only when the rope is in fairly good condition; when badly chafed or worn the load should be reduced in proportion.

A wood or lag screw, when made in the form of an eyebolt, should never be used to hang any hoisting tackle on. Wherever possible, the safest way to hang such tackle is by passing the shank of an eyebolt through the floor or beam, properly protecting the wood by a large plate washer and nut. It frequently happens that a chain or rope sling can be used by passing it over a properly secured timber. There are several good ways of doing things, and many wrong ways. Care should always be used to see that they are done in a good way. Case after case might be enumerated; but enough has been said to enable any person entrusted with this

THE TRAINING OF ENGINEERS.*

BY SIR H. FREDERICK DONALDSON, K.C.B.

I propose to deal more particularly with some aspects of the educational system, the thorough appreciation of which I regard as of paramount importance for the future well-being of the engineering profession as a whole and of the prosperity of this institution in particular. Probably there is no recent action taken by this institution which will have a wider effect in the future than the decision to establish a method by which candidates for admission as graduates, or associate members, shall give evidence that they possess that knowledge of those scientific principles which the practice of the profession of mechanical engineering in the present day more and more insistently requires. The introduction of these educational tests aims at securing the greatest possible advantage to the profession at large, while at the same time its object is to raise the status of membership of the institution to a plane even higher than has already been attained. Even if such an aspiration were not very much to be desired on its own account,

* Abstract of presidential address delivered before the Institution of Mechanical Engineers, April 18, 1913.

it may certainly be regarded as necessary for the maintenance of our national position in the engineering markets of the world, and as enabling us successfully to meet international competition, the existence of which is so keenly felt on every side.

The application of science to problems of mechanics, of metallurgy, and of electricity, is in itself an object to aim at, but added to this is the following. The tone of mind which results will tinge actions in other directions, where higher qualities of treatment of the daily routine of manufacture are needed to arm us for the battle of trade competition; it will foster our efforts after progress, whether it be in quality, quantity, or value of engineering trades, and will assist in meeting the difficulties of each day's work. No one will gainsay the statement that engineering in all its branches is a practical profession, and though I am endeavouring to press upon you the urgent necessity for sound scientific knowledge as one of the assets of every individual engineer, it would be but half the tale if this appeal aimed only at closer application of science to every-day problems. Practical work is absolutely essential if a practical profession is to be carried on effectively, and no effort should be spared to impress this upon all concerned.

It is probably within the recollection and experience of many here that those who press, and quite rightly press, the importance of scientific and theoretical study as training for an engineering career, also plead very hard for an adequate recognition of their efforts from employers. They invite their cordial co-operation, and sometimes scold them for a backwardness in affording it. Their aspiration for co-operation can be given the fullest sympathy, but I am none the less inclined to take teachers themselves to task with regard to some of the advice they give either explicitly or tacitly to their students. Too many young men adopt the idea when they have submitted themselves to a course of technical study, and have perhaps displayed conspicuous ability therein, that they leap from that, and that alone, to a level which at once entitles them to look for and expect a lucrative position in engineering works. This is entirely erroneous, unless they have an actual practical training as an additional asset. I do not complain of the natural ambition which probably helps towards such an idea on the part of the young man, but I do seriously complain of those teachers who foster such an error. If teachers meet occasionally with an apparent lack of appreciation on the part of employers of the theoretical and scientific training which they have given to their students, I think that, if enquiry were made, there may be something to be said for the employer. It will very possibly be found that the employer regards such half-trained men with some suspicion, and possibly even he may have suffered from an engagement of such a young man to an extent which leads him to say that, however much he desires a man thoroughly trained both in theory and practice, he cannot afford to employ a man trained only on the former line, and that if he can only get training on one line he would prefer the practical to the theoretical man.

For myself, I desire to secure the services of men who are thoroughly trained, and I speak from some experience of their value, but I regret that I also speak from experience when I say that there is too often a neglect of the practical workshop course. I am convinced that such an omission of an essential part of the training is most disadvantageous to the student himself, as well as to the ultimate strength of the profession as a whole. One of the results of this tendency is that, when a vacancy has to be filled, it is by no means easy to find a man who is equipped with good theoretical and scientific training, coupled with a thorough workshop training, and ability to apply the one to the other in an efficient manner. A good portion of the blame for this must lie at the door of some of the teachers, and I can only hope that any to whom such charges apply directly or indirectly, may without delay recognise that if they desire, as of course they do, the co-operation of employers in forwarding the interests of their students, they must see to it that they not only avoid the inculcation of such erroneous ideas into the heads of those under their charge, but also must adopt the line of impressing on them that for a practical profession they must be practical men, and, in order to attain that, they must submit themselves to thorough practical *as well as* thorough theoretical training.

One may ask oneself how it happens that men who spend their energies as whole heartedly as the teachers in engineering colleges and the like do, in the interests of the student entrusted to their care, make the mistake which I am suggesting they do make. There can doubtless be several answers given, but probably the true one is that there is something wanting in the training of many or most of those of whom we complain. If we look round at the leading lights of the engineering educational firmament who have themselves, before embarking in teaching work, not only passed through a thorough workshop training but have followed that by a considerable amount of practical work and experience, we shall not, I think, find that they are offenders in the sense of which I am speaking. It would seem that it is rather those who have not themselves undergone a workshop training or, if they have done that, have taken up teaching before they have accumulated an adequate supply of practical experience who are most prone to decry the importance of practical training and experience, and thus by their explicit and tacit advice throw impediments in the way of a young man carrying his education through in the most complete manner. Such men may be, and probably are, thoroughly conversant with theory, and most perfectly competent to teach that side of their subject, but if they are themselves lacking in practical training and experience it must necessarily follow that their powers of imparting knowledge of the application of theory to practice must be stunted and narrowed. If a man is to be able to teach the application of science to practice efficiently, he must himself be not only a scientist, but a practical man as well. In the interests of the teachers themselves and of the students under them, this surely ought to be recognised.

If it could be arranged that every teacher could, concurrently with his teaching, be engaged on practical work of a nature allied to the subject taught by him, great advantage would undoubtedly accrue to the teacher and the student. Such a departure would, of course, entail considerable reform in the present methods of teaching, and the allocation of the teacher's time, but that need not be regarded as impossible, because it has in fact been found practicable in other countries. Of course, in the larger educational centres the teachers do have some opportunity of keeping in touch with practical needs from various investigations and researches they are invited to make in the education laboratories, but if they could, in addition to this, be actually engaged on practical or even commercial work, as well as laboratory experiments and investigations, the authority with which they could direct the studies of their students must undoubtedly be enhanced.

I hope I shall not be thought to have spoken too critically, but if an excuse be necessary, I would plead the great importance which it has for the whole profession—I will on that account even go further, and crave indulgence for addressing also a few cautionary remarks to students and young men. I have not infrequently met cases of young men who, when questioned as to their practical training, advance the statement that the work they have done in their college workshops and the like is equivalent to a workshop training. I have nothing to say against the existence of such a college workshop as a place where a certain amount of manual dexterity may be acquired as a sort of relaxation from the regular work of the study or the lecture-room. It cannot, however, be regarded as in any way approaching what is really required in the way of practical training, or as capable of giving any approximation to the value of the experience to be gained from work in the shops under real working and commercial conditions.

Supposing that the statement, that the importance of practical work is very great, will not be seriously controverted, I must add that all the advantages cannot be regarded as fully secured, even when courses of theoretical study have been combined with workshop training. When the primary courses have been completed, the education of an engineer must still go on by the acquisition of experience, and from this point of view the engineer's education is never finished. Sir A. Trevor Dawson, in an address he delivered last autumn, seems to me to urge his hearers very strongly on these lines, for

in more than one sentence he pointedly refers to the importance of the acquisition of practical experience by young men, even at a temporary shortening of salary. For instance, he said: "For the moment it is enough to establish that experience is a dominant consideration. This cannot be too forcibly emphasized, for young men are at times prone to seek advancement without carefully considering whether that which looks like advancement will conduce to the winning of the experience so invaluable in future work." To this I cordially assent.

In my opinion, before such practical experience can be properly assimilated, a workshop training is essential. Its value is very great all round, for it covers a great deal more than manual dexterity. For instance, it affords a man an insight (not otherwise attainable) into the working of men's minds, men perhaps of rather a different class from himself, but who, undoubtedly to start with, are head and shoulders above him in their ability and in their methods of handling and carrying through particular, and it may be very important, operations. Moreover, he will, of necessity, from working at the bench and the like, even if he keeps his eyes only slightly open, become acquainted with the point from which various matters are viewed by the operative, and he will undoubtedly find that study, not without its uses in after life. He will recognise the fact that the user of a machine will be most cognisant of the peculiarities of the particular piece of mechanism with which he has to do, and it is useful to a young man to watch and see how such a man will care for and nurse the peculiarities of his machine in order to secure the best results. Of course, in this case I am speaking of a good workman, of whose class we may be thankful to-day we have a fine supply; but the young man will also find it instructive and useful to study the doings of a less careful or even a careless workman, of whom there are also some, as he will thereby learn how not to do it.

Perhaps some apology is needed for dwelling so long on this particular portion of my subject, but I feel as strongly that a man with only technical and no practical training is far from being a thorough engineer, as that a man with practical and no technical training is insufficiently equipped to meet the conditions of engineering work to-day. The competition which exists, both at home and abroad, spurs, and should spur, us to the greatest efforts after ideal perfection. There appear to be two desiderata for meeting this competition: (1) Our quality of output should continue to be superior to that of our competitors; (2) our selling prices should be if possible actually, but at anyrate relatively, lower than theirs. The former of these demands that the machinery and appliances should be the best of their kind, that the men engaged should be fully qualified from their personal skill for their use, and that the association of these two should be most closely effective. The latter requires that the methods of doing the work of production should be organised on the highest lines of efficiency, having special regard to the avoidance of waste of either material or energy. It will perhaps not be out of place if I attempt to sketch out methods of organisation which will help to attain the desired ends, presupposing that the directing minds are both practical and scientific.

While quality must of course stand first, quantity which results from cheapness of production follows close in the scale of importance. Cheap production postulates the use of every labour-saving appliance which can be economically employed, large powers of output and widespread consumption of the product. This entails most strenuously watchful management to control "on charges" at the lowest possible figure; it involves organising power of a high order as regards supply of material, adequate machinery and arrangement thereof, the proper distribution of labour of the quality each operation requires, and the maintenance of the whole of the organisation at the highest point of efficiency. It is here that men highly trained both scientifically and practically will prove their worth and show their value in the ultimate profit and loss account.

Both theory and practice are needed to so distribute the various qualities of labour which are required for manufacturing, as distinct from fitting, operations. Cheapness of production must necessarily follow manufacturing lines, but all classes of labour are required for proper organisation. The high-class fitter, though required to as great an extent (even if not greater) as in the past, is less prominently apparent as a direct producer, but he really is one of the main sources of power to enable cheap manufacture to be effected. The less skilled and therefore cheaper labour is apt to be regarded by the casual observer as the main and actual producer, and the highly-skilled preliminary and maintaining force is sometimes too much neglected. I must therefore not be understood to advocate cheap labour as against the more skilled and therefore more expensive labour, though I admit that present-day requirements do involve a change of direction in the employment of the latter; at the same time it is well to make it clear that not only is the highest quality of skill required on the part of the workman of the best class, but even more of the class are needed than formerly.

Not only is this so, but the increased demand which follows cheaper production leads to the employment of a large increase in the number of operatives who, though partially skilled, have not attained to the level of the highest class. I base this statement on a large number of statistics which were compiled and published some years ago by the United States Government. It was shown thereby that, no matter what the product investigated might be, a large output at reduced selling price led to an enormously increased demand for that product, with the result that not only was there a large increase in the number of men of the highest skill required, but there came into existence an immense volume of work with good wages for operatives of less skill, for whose services there was no use under the old system. Any methods, therefore, which will have such a result must be beneficial not only to the trade of the country but to the community at large, and any employer who so directs his works that he is able to pay wages on the highest and widest scale, and yet produce at prices capable of competing on favourable terms in foreign markets, is little short of a true benefactor to his country, and is well deserving of the profits of his enterprise which he is able to secure. I say that to attain such results he must not only have and use brains himself, but he must employ brains of high practical efficiency in all branches of his undertakings.

While I am pressing for mental qualities as necessary in those entrusted with administrative and executive duties, it must not be overlooked that it is as requisite that the mental calibre of the rank and file should also be higher than in the past. This is required, because machinery itself needs even more skill in its use, and the nature of the work to be done is more precisely stated, than formerly. I do not mean for one moment to decry the skill and ability of mechanics of the past. On the contrary, I have the utmost admiration for the excellence of their work when using machines of less precision, and methods which depended in a way more upon individual skill and initiative than is the case now. The case of a mechanic of the old class is really quite a good one to take for comparison of then with now. He turned out work which was, and indeed in many cases is to-day, second to none, but he attained his high quality to a large extent by trial and error when it came to fitting two pieces of mechanism together; he was not in a position to adopt the process of to-day, called "assembling." The direction given to him by the drawing was in fact inadequate, for the subdivision of an inch by the system of repeated bisections left him without real guidance as to the closeness of the fit which he was required to obtain. His appliances for fine measurement were conspicuous by their absence, and his high quality of work was, perhaps, not unaffected by his health on a particular day. In a word, though he produced work of the highest quality, he did so without any actual knowledge of the fineness of the dimension to which he was required to work. Contrast with this the more modern system; the mechanic of to-day is, in up-to-date shops, given the dimension to which he has to work, in decimals of an inch. Measuring appliances of adequate precision are in his hands or available for his assistance, the quality of the work required is at least as high, but he approaches his task with knowledge of what is required as to the nature of the fit for which he has to prepare, and his machine is probably much more accurate in its action. It is not, therefore, unreasonable to expect, nor is it unusual to obtain, equal or even better quality of work at less expenditure of material and energy, and cost.

These remarks deal of course with men of the highest skill, but a word seems necessary as to those of less high quality whose services are required for work of a repetition

character. Here the operative has gauges, templates, and the like, to which he has to work, and he is not so much concerned with knowledge of actual dimensions, for all provision of that sort is embodied in the manufacture of the gauges themselves; if, as should be the case, he has gauges of high and low limit given him between which his work should "go" and "not go," it is manifest that, as less actual skill is demanded from the man, and what is demanded can be secured without a long apprenticeship, the remuneration of such labour is less, while the production is more rapid and the consequent selling price is reduced. It must, however, not be overlooked that these provisions involve a considerable amount of the preparatory work which must form "on charges" on the finished product. It is there that the control of such charges, at a figure which shall not be overburdensome, requires the utmost care on the part of the executive and administration. For this, the trained mind will be the most useful safeguard.

Now turn to the office and workshop to select examples of cases where economies and improvements in working will follow the greater use of scientific attainments coupled with practical application. For the more ready apprehension of what follows, it is perhaps well that the meanings attached to "Administration" and "Executive" should be defined. By the administration is meant the controlling powers of the undertaking, whatever it may be, and the staff directly attached thereto, for arranging and administering the whole concern. The term executive is used to mean those who, under the administration, are entrusted with the control of personnel, machinery, and work, for obtaining the output of the product with which the undertaking is concerned.

There will be no dissentient voice against the statement that that undertaking is best equipped which has in its administration not only high quality of business ability, but a firm basis of scientific and practical knowledge to guide its actions in framing the policy and giving it first-hand power to form clear and reliable opinions as to the correctness of the operations carried out by the executive under its control. It seems in fact to be a truism, that the administration must be fully informed of its own knowledge of the scientific and practical possibilities of a case, before it can effectively lay down a policy to be followed. There are few more fruitful sources of loss in working than to lay down a line of policy on insecure foundations, or on lines which are either totally impracticable of realisation without excessive cost, or which are so far unscientific as to shake the confidence of the executive in the soundness of the judgment of the administration. Similarly, the executive must be equally conversant with scientific principles as well as thoroughly master of all practical technical details. In a word, knowledge and practical experience must be the undoubted possessions of both branches, for there is no part of any engineering establishment which will not be more benefited by the services of men holding this combination of qualities, than by men qualified only with practical experience. Conversely there is, in my opinion, no possibility of an establishment being successfully worked by men having only a scientific and theoretical knowledge without practical training and experience in addition.

Let us now try to follow up another line. Every undertaking which aims at keeping at least abreast of current requirements must be prepared to spend some money in experiments, investigations, research, and the like, and there can be no question that, on the one hand, in the inception of such work, in its arrangement and in its operation, the presence of the mind scientifically trained is essential, and that for practical work, on the other hand, the scientists employed should also be practical, in their methods of approaching and handling the investigation or research, and in the application of the results presented. Some will consider that the branch for carrying out this class of work should be primarily under the direct control of the administration, while others will hold that it is more essential to the executive and should be primarily part thereof. The results of the work are undoubtedly wanted by both, by the administration because its policy may be affected, and by the executive because its economies in working may be materially assisted thereby. On the whole it would probably be best to entrust the control of the branch to the executive with an arrangement that all important results should reach the administration simultaneously with the executive among the reasons for this preference might be instanced that the executive will find it advantageous to have a considerable number of small experiments carried out which could hardly be honoured by so high a title as "research," but which none the less may have great economic value. For such work the executive would be primarily interested.

Any research of a larger or more expensive nature might and probably should only be undertaken with the concurrence of the administration. In fact, in order to prevent the expenses of the branch becoming so great as to be overburdensome on the whole undertaking, it might be found reasonable that the administration should keep close financial control of such work, by laying down that not more than a definite sum should be expended on any one investigation or research without its specific authority. This is the system in use in many places, and has been found to work with satisfactory results. At present, inadequate attention is too often afforded to such matters, and I could quote many examples. I will take one. It is quite likely that there are not a few mechanical engineers who fail to appreciate the considerable effects which even small differences in temperature in heat treatments may have on ordinary steel. It may even surprise some to hear that a variation in one temperature of a series of treatments, which would be represented by a number of degrees much less than those between freezing and boiling-point of water, will so act as to make the material, which with one series is suitable for some purposes, entirely unsuitable with another series. Let me quote from actual trials what this means. Ordinary steel, containing about 0·53 per cent. carbon, fairly high in silicon (about 0·18) and manganese (about 0·84), was investigated, and with certain treatments gave the following mechanical tests: Yield-point, 36 tons per square inch; breaking load, 56 tons per square inch; elongation, 8 per cent. on 2in. effective length. The same quality of steel, by varying heat treatments (heated 790° C.), oil-quenching (about 80° C.), and reheating (about 330° C.), gave approximately the following results: Yield-point, 68 tons per square inch; breaking load, 84 tons per square inch; elongation, 2 per cent. on 2in. effective length. When the same initial heating and oil-quenching were coupled with a reheating temperature raised by only 70° C. (that is, to about 400° C.), the test results were approximately as follows: Yield-point, 42 tons per square inch; breaking load, 64 tons per square inch; elongation, 16·5 per cent. on 2in. effective length.

With such varying results there seem to be very good grounds for pressing for scientific methods in actual work, for no amount of rule of thumb or expert eye could ever ensure uniformity in results with so narrow a margin in the matter of one temperature. It seems clear, therefore, that there is essential need for some arrangements which shall not depend upon the natural gifts or unaided ability of a single individual, and that some system of pyrometry is called for as a protection against failures. The installation of apparatus of this sort is by no means common, and is apt to be regarded by many as somewhat in the nature of a luxury. It ought not to be so regarded, for nothing short of it will ensure prevention of failure and waste arising from mistakes in heat-treatment operations. Such apparatus would not be without its use in the ordinary miscellaneous foundries, as well as those specially provided for particular products, for more uniform results could probably be got with castings, if greater attention were paid to the temperature of the metal when poured and subsequently cooled, and even to the speed at which the material was reduced to and from a molten condition. If scientific knowledge, coupled with the necessary practical experience, is brought to bear upon such matters as these, the undertaking will reap large advantages in higher efficiency of output, less waste, and consequently actually cheaper production.

Many other examples in support of the ends at which we should all aim could be brought forward, and probably many will occur to your minds, so your time need not be occupied in suggesting them. I trust, however, that the object in view may be clear and in no way obscured by my method of presenting it. What it amounts to is this: the engineer of to-day has more varied calls on him than in bygone times, and he must therefore be more highly equipped to meet such calls. He must be to a large extent a scientist, but he must also be,

in every sense of the word, a practical man. His views must be wide, and there should be nothing either petty or narrow in his dealings.

Research in the hands of firms and engineering undertakings, has already been advocated, and no one would wish to see such efforts in any way hampered; but if it were possible to co-ordinate the work more than is done at present, and also to place the results at the disposal of the profession more readily than is now the case, great advantage may be expected to result. Is it not worth considering whether enquiries should not be made to see if an Engineering Research Committee, the bounds of which should be much wider than membership of this Institution alone, could be got together with a view to organising, co-ordinating, and assisting research, more particularly for engineering purposes? The success which has attended the Engineering Standards Committee might be regarded as holding out hopes of similar possibilities of success for an Engineering Research Committee, so far, at anyrate, as obtaining the gratuitous personal assistance of those best competent to assist in particular directions. It must be admitted at once that the expenses attaching to an Engineering Research Committee must necessarily be heavier than has been the case with the Engineering Standards Committee, for though individuals may be ready to give their time and attention to meetings and the general direction and co-ordination of different researches, the actual carrying through of the researches themselves must necessarily be a costly matter.

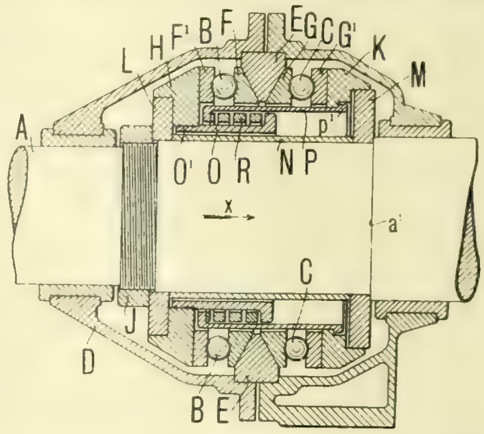
This Institution spends a certain amount of money annually in research, and it might well be that part at anyrate of the money which we are able to devote to individual researches might be better expended in helping to support the work of a Central Engineering Research Committee, and that other societies and institutions might also be ready to allot funds for a similar object. I am well aware that grants in aid of research are already made from many sources, notably from the Royal Society, from the Government, as well as from various private firms and individuals, and some of these might possibly be tapped for the more specific researches which would fall within the scope of the Engineering Research Committee. The advantages which would seem to accrue from such a step would be the prevention of a considerable amount of overlapping work; the carrying out of individual researches to absolute results; the publication of such results, and the inclusion in such publication accounts of private researches and experiments carried out by those who would associate themselves with the Engineering Research Committee, and would be willing to place results of work privately carried out at the general disposal of the Committee. In time, the Committee would doubtless acquire so large an accumulation of data as to make it the first source upon which the public would draw for information as to any research already effected, and as to the possibilities of extending research on lines which might at the moment seem to require investigation.

The subject is, of course, a very large one, but it covers a combination of applied science and practice, and as such falls readily within the scope of the subject, or subjects, with which I have been endeavouring to deal in this address. It is, however, only right that I should say that the suggestions I have made with regard to this Research Committee are made on my own responsibility, and must not be regarded as in any way representing the views of other members of the Council. I have not so far discussed the matter with them, but should the Council be disposed to regard the idea with favour, it may be that they would think well to take the initiative in instituting enquiries as to whether co-operation could be arranged from private individuals and from other societies, to consider the practicability of the whole subject, and the possibility of the attainment of any advantage by a move in this direction.

DOUBLE-ACTING BALL THRUST BEARING FOR HORIZONTAL OR INCLINED SHAFTS.

DOUBLE-ACTING ball bearings having a system of balls operative for each direction of thrust, in the case of shafts arranged horizontally or on an incline, present the disadvantage that axial play arises in that system of balls which has no load on it at the particular time. In consequence thereof the balls of this system and the rings on which they run are easily shifted out of their right position by the action of their own weight or by centrifugal force. When the direction of the thrust is changed such shiftings may give rise to jammings, which easily result in the running hot of the bearing or at least a rapid wearing out of its parts. This injurious play very soon arises also in the case of thrust bearings which are originally built without play, in consequence of the unavoidable wear of the co-operating parts. To overcome these disadvantages, Messrs. Krupp, of Kiel-Gaarden, Germany, have designed and patented the arrangement illustrated, in which the axial relative positions of the two ball systems are always maintained even in an unloaded condition, so that shiftings are rendered impossible.

Referring to the illustration, A is a shaft, the propeller shaft of a ship for example, which transmits the thrust of the propeller to the ball thrust bearing rigidly arranged in the ship. Between the two halves of the casing D of the thrust bearing is inserted a thrust ring E against which the inner running rings F and G of the ball systems B and C bear. The corresponding outer ball running rings F^1 and G^1 bear against annular intermediate pieces H and K, which are movable to a slight extent in an axial direction upon rings L and M. These rings L and M are held apart by a sleeve N, and are prevented from moving in the direction of the axis of the shaft by a shoulder a^1 on the shaft contacting with the



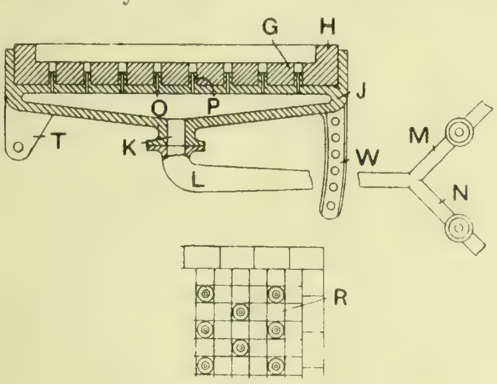
DOUBLE-ACTING BALL THRUST BEARING FOR HORIZONTAL OR INCLINED SHAFTS.

ring M and a collar J mounted on the shaft contacting with the ring L. The sleeve N is surrounded by two cylindrical sleeves O P of different diameters, which have on their inner ends flanges, turned towards each other and retain between them a powerful helical spring R for which the flanges serve as abutments. The outer end of the sleeve P engages by means of a flange p^1 a seat turned out in the intermediate piece K, while the outer end O^1 of the sleeve O is rigidly connected by a screw thread, with the intermediate piece H, which latter is constructed in the form of a nut. The screwing of the intermediate piece H more or less on to the sleeve O serves to regulate the tension of the helical spring R according to requirements.

For the explanation of the action of the apparatus let it be assumed that the thrust set up in the shaft acts in the direction of the arrow x. The transmission of this thrust to the casing or its foundation then takes place through the medium of the ball system B, that is to say, through the collar J, the ring L, the intermediate piece H, the running ring F^1, the ring of balls B, the running ring F, and the thrust ring E. When the thrust takes place in this direction there is no load on the ball system C. Any shifting of the balls and running rings are, however, avoided by the sleeve P, which is under the influence of the helical spring R, thrusting the parts of this ball system against the thrust ring E, some play taking place between the parts K and M, as can be seen from the drawing. If the direction of the thrust set up in the shaft changes, the force of the thrust will be transmitted to the casing D through the medium of the ball system C, through the parts a^1, M, K, G^1, C, G, and E, the same helical spring R which previously pressed the system C against the thrust ring E, now holding the parts of the ball system B together in the same way. It will therefore be seen that the position of the parts of both systems with relation to the shaft A is permanently preserved unchanged, no matter in which direction the thrust acts.

SURFACE COMBUSTION HEARTH FOR LANCASHIRE AND CORNISH BOILERS.

A CONSTRUCTION of hearth utilising the principle of surface combustion and applicable to boilers of the Lancashire and Cornish type has been designed and patented by Prof. W. A. Bone, of the Leeds University, and Mr. C. D. McCourt. It is shown in the accompanying cuts, Fig. 1 being a longitudinal section through the hearth, and Fig. 2 a part plan view showing one manner in which the hearth may be built up. Fig. 3 illustrates the arrangement and disposition of the hearth within the flue of a Lancashire or Cornish steam generator. G is the hearth of refractory material and provided around its sides or edges with low walls H, which serve to retain the bed of refractory material in granular or fragmentary condition in position. The hearth is contained within a carrier J of metal. This carrier is made hollow and is in communication with the gas and air supplies. Connection with the gas and air supplies is effected through an aperture K and a supply pipe L; this pipe being in turn connected with an air supply pipe M and a gas supply pipe N, each controlled by a cock. The connection of the interior



FIGS. 1 AND 2.

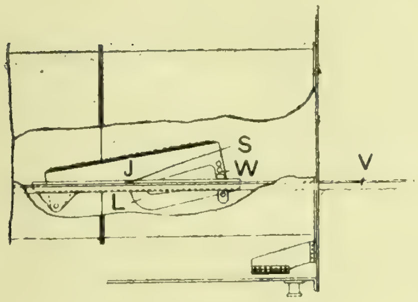


FIG. 3.

SURFACE COMBUSTION HEARTH FOR LANCASHIRE AND CORNISH BOILERS.

of the carrier with the atmosphere is afforded through a number of narrow apertures O, these apertures being formed through bosses P on the upper plate or face of the carrier. The hearth is composed of a number of firebricks R which are laid on the upper face of the carrier. The hearth is made of such thickness that the tops of the bosses P are slightly below the upper face of the hearth, in order to prevent the bosses from being burned. The cross-section of the apertures O is such that the speed at which the combustible mixture passes therethrough is greater than the speed of ignition backwards of the gaseous mixture in the apertures.

The bed of refractory material is piled on the hearth, being in pieces of from 1in. to 1½in. diam. and of such a character as to withstand the temperature produced. Thus where coke oven gas is employed, a high temperature being thereby obtained, calcined magnesite is found to be a suitable material. When, however, the gas employed is one which does not produce so high a temperature, a less refractory material may be employed in the formation of the bed, for example, firebrick may be used when blast furnace gas is employed. The carriers J for the hearths are mounted on a carriage S, the connection of the carrier with the carriage being effected by means of brackets T on the carrier and pins on the carriage. The carriage is in turn mounted on and movable in relation to runners V disposed within the flue and extending some distance beyond the front of the steam generator so that the carrier with hearth and bed of refractory material can be properly positioned within the flue or wholly withdrawn therefrom for inspection or repair. To enable the heat radiated from the incandescent bed of refractory material to be thrown or directed in any desired direction, *i.e.*, either directly upwards to the flue wall above and adjacent to the hearth or to a greater or less distance along the flue, the carrier is so mounted that it may be placed either horizontally or inclined at an angle to the horizontal. To enable the carrier to be maintained in an inclined position, it is provided on its end or side opposite to that to which the brackets T, with downwardly extending arms W. These arms are provided with holes through which pins can be passed, the inclination of the carrier, and therefore of the hearth, being adjusted by alteration of the positions of the pins in the holes. The pivotal mounting of the carrier also permits or facilitates the discharging of the bed of refractory material, the carriage being, when this operation is necessary, wholly withdrawn from the flue and the carrier turned about its pivotal connection with the carriage.

The gas is supplied under a pressure of, say, 1lb. per square inch and the air at a similar pressure. In starting up the gas controlling cock is first opened and the gas as it issues from the top of the bed of refractory material, is ignited. The air controlling cock is then opened, the air mixing with the gas in the supply pipe and the flame as a consequence becoming more and more aerated until a point is reached at which it strikes back and an accelerated combustion takes place within the bed of refractory material, no flame appearing above the top thereof. The proportions of air and gas are then so adjusted that if the supply of air be slightly decreased, a slight appearance of flame on the top of the bed of refractory material results. When the supplies of air and gas have been adjusted as described, the gas and air are present in the combustible mixture substantially in the proportions theoretically necessary for complete combustion. The continuous combustion which takes place within the bed of refractory material maintains it in a state of incandescence and a large amount of heat is radiated. The products also contain a very small percentage of free oxygen, for example, the proportion may be as low as 1 per cent.

Where it is desired that the whole of the combustion shall not take place within the bed of refractory material, and that a proportion of the gas shall burn above the bed with the formation of flame, the proportions of air and gas are so regulated that the combustible mixture contains a proportion of air less than the proportion required for complete combustion, the further supply of air necessary being admitted above the bed so that the flame issuing therefrom is supplied with the further amount of air required to effect complete combustion.

When the arrangement is applied to Lancashire, Cornish, or other steam generators which have been constructed and erected for firing with solid fuel, some or all of the firebars are removed so as to enable the runners and carriage, carrier and hearth to be placed within the flues or combustion chamber. In such cases it will be necessary to close completely the front of the steam generator, all air necessary for complete combustion being contained in the combustible mixture, except it be required to burn the gas with the appearance of flame above the bed as mentioned above, in which event the closure to the furnace front is provided with controllable air admission means. The gases employed should be substantially free from dust so as to avoid clogging the bed of refractory material. When the gas is not free from dust, the periodical renewal of the bed will be necessary.

Underground Electric Railway System for Sydney.—Considerable amendments have been made to the scheme submitted in 1912 to the Minister of Public Works for the improvement of the Sydney railway system by the Public Works Department in conjunction with the Chief Railway Commissioner. Under the scheme now proposed an underground loop railway will be built, with connections to the eastern and western suburbs, and to North Sydney by a bridge to Milson's Point. The Cabinet has approved of the construction of the first section of the railway and the survey has been begun. Plans and specifications are in course of preparation so as to enable the construction to be commenced as soon as possible after the sanction of Parliament has been obtained.

THE LONGITUDINAL STABILITY OF SKIMMERS AND HYDRO-AEROPLANES.*

BY J. E. STEELE, B.SC.

(*Concluded from page 438.*)

The Donnet-Léveque Hydro-Aeroplane.—This is a bi-plane (Fig. 6), whose water-tight, torpedo-shaped fuselage is on the lines of a skimmer, having the characteristic step of the latter. Near the blunt nose of the fuselage there is a horizontal elevator, which prevents the nose from diving when alighting, and the machine from consequently tripping over. When sufficient speed is attained the after end lifts, and the machine glides on the sloping front. After skimming on the surface of the water for about 50 yards, an elevation of the rear elevator causes the machine to rise bodily into the air. The head resistance is reduced to a minimum by the propeller, with its Gnome engine, being placed at the other end; the wash from the propeller thus encounters no obstacles.

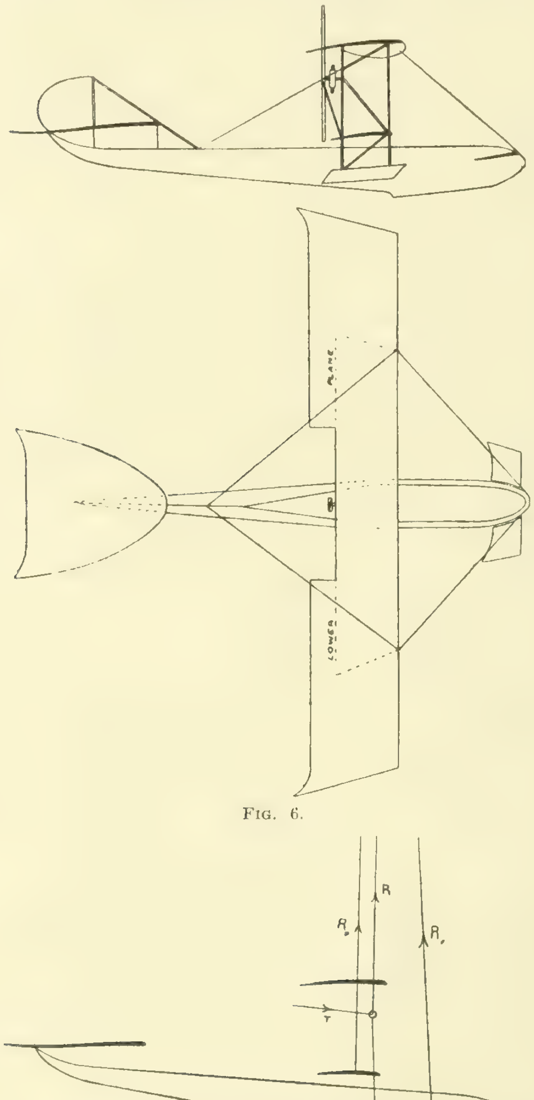


FIG. 6.

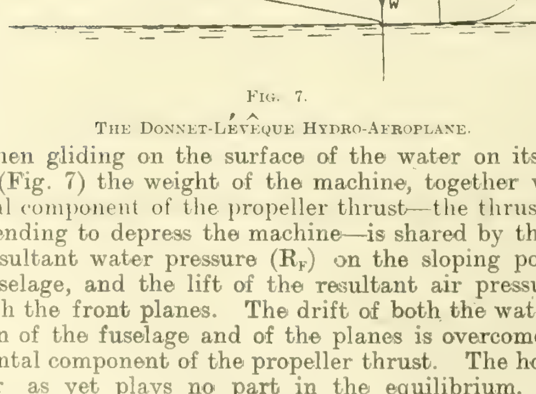


FIG. 7.

THE DONNET-LÉVÊQUE HYDRO-AEROPLANE.

When gliding on the surface of the water on its sloping front (Fig. 7) the weight of the machine, together with the vertical component of the propeller thrust—the thrust in this case tending to depress the machine—is shared by the lift of the resultant water pressure (R_F) on the sloping portion of the fuselage, and the lift of the resultant air pressure (R_P) on both the front planes. The drift of both the water-borne portion of the fuselage and of the planes is overcome by the horizontal component of the propeller thrust. The horizontal rudder as yet plays no part in the equilibrium, as it is probably neutral. The three forces, R, T, and W, meet in the point O.

As was seen when considering "Miranda IV.," an increase in the propeller thrust will cause the machine to rise into the air, so that steering in a vertical plane can be accomplished by increasing or diminishing the thrust of the propeller. An increase in propeller thrust then tends to cause the machine to rise, and it will raise it altogether into the air when the thrust gets large enough. When the machine is altogether air-borne R_F suddenly disappears almost entirely, as now air acts on the sloping front of the body. The result is that R_P alone is left, increased in magnitude by the increase in the angle of attack, and as the angle of attack also shifts the centre of pressure aft, there is a considerable unbalanced couple tending to overturn the machine forward. The horizontal rudder must now come into play to restore equilibrium, and to give it the requisite anti-clockwise moment about G the rudder must be depressed. In order that the machine may quickly assume the new position of equilibrium it must be longitudinally kinetically stable. Owing to the less dense medium impinging on the sloping part of the fuselage, the drift of that part of the machine is almost entirely done away with, and the unbalanced part of the propeller thrust will accelerate the speed.

As horizontal flight in air is outside our province, we will pass to the time when, the flight over, the pilot is just about to stop the motor in order to volplane to the water. That there may be no sudden alteration in longitudinal stability when the motor is stopped, the line of action of the propeller thrust should pass near the centre of gravity of the machine, otherwise a large unbalanced couple will act till the countervailing horizontal rudder couple is brought to play. It is well to design so that the propeller thrust may not pass exactly through the centre of gravity, but at a certain distance from it, so that on its removal the machine may naturally tilt to the best angle for volplaning.

When alighting the reaction R_F of the water on the fore part of the fuselage leaps into existence, and in a much intensified form, as the nose will probably be driven deeply into the water, though there is a limit to this depth determined by the horizontal fins fitted near the fore end to prevent diving too deeply. If the augmented reaction R_F is at too great an angle to the resultant of the combined air-pressures on the planes, the common resultant will swing so far forward that the unbalanced couple will bring the after end down with a jar if the resultant passes in front of the intersection O of the other forces, or trip up the machine if it passes too far behind O.

The inclination of the flight path to the horizontal influences the longitudinal stability, which falls off as this inclination increases. When the angle reaches somewhat less than twice the angle of attack, the machine becomes longitudinally unstable. The head resistance, however, has a great effect on the above, as with a greater head-resistance instability would not occur till a greater inclination of the line of flight to the horizontal than that given above was attained. This shows the advantage of rising into the wind, as the relative velocity of wind to machine is increased.

Care must be taken when alighting, as the pilot may not have near objects to guide him as to his real speed relatively to the surface of the water. If the speed of the machine be V, and the wind happens to blow with a speed v in the same direction as that in which the machine is travelling, the pilot will not be aware of the change in speed relatively to the water surface, his speed down the wind will now be $V + v$, and if he attempts to take the water at this speed an accident may happen due to tripping. If, however, he runs up the wind, his speed will then be $V - v$, and he can alight in safety.

To the assumptions which have been made in the case of the "Flying-Fish" must be added the following: The wash on the tail plane produced by the front plane alters the angle of attack of the former, but probably to a small extent. As the course of the stream lines is unknown, the wind direction as it approaches the rear plane is taken as parallel to that at which it meets the machine.

The gyroscopic effect due to the angular momentum of the propeller and of the rotating engine—if that type be fitted—mixes up the two sets of oscillations, symmetric and asymmetric, and, if these happen to have nearly the same period, resonance effects would be set up, making the machine an uncomfortable one to those on board. The gyration effect due to the above two causes also influences the steering of the machine. If twin screws are fitted, working against one another, then the gyrostatic effects of the rotating inertia of

* Paper read at the Spring Meetings of the Fifty-fourth Session of the Institution of Naval Architects, March 13th, 1913.

the propellers, rotating engines, also the additional effects due to propeller torque and unbalance of engine, are all eliminated. In some aeroplanes there are contrary-working screws worked by chain drives from one shaft, one chain being crossed to give the reverse motion. There is also a motor in which the propeller and engine both revolve, as in the Gnome motor, but in opposite directions, so that their gyroscopic effects cancel. We will discuss the case of the engine with propeller attached revolving round the shaft, as this has the greatest effect on both the steering and the longitudinal stability of the machine.

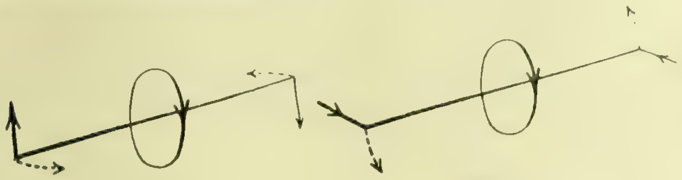


FIG. 8. FIG. 9

By the principle of conservation of momentum, the axis of spin tends always to keep pointing in the same direction, say due east, even though the machine be carried about by wind currents. If by gradually altering the angle to the horizontal by steering in the vertical plane, we apply a couple to the axis of spin tending to tilt it up, the axle will commence to precess in a certain direction determined by the direction of spin and of the couple applied. The greater the magnitude of the couple applied the greater will be the rate of precession. It will be seen from the diagram (Fig. 8) that, with a right-handed propeller and engine turning with it, if a couple be applied by the machine being steered downwards, the precession will cause the head to turn to the left. If this precession be retarded by applying an opposing horizontal couple by means of the vertical rudder, then the axis of spin will tilt further down at the fore end. If, on the other hand, we accelerate the precession by giving the machine some helm, the whirling parts will tend to cause the forward end to lift.

If a turn is made to the left (Fig. 9), the after end of the plane, owing to precession, will dip down; a sickening feeling to the pilot, who almost invariably turns to the right with a right-turning propeller. Again, the greater the steering couple applied, the greater will be the tendency to dip, as the greater will be the precession. When the aeroplane is to be turned in the horizontal plane, then, not only must the vertical rudder be actuated, but the horizontal rudder must be moved to overcome the gyroscopic influence. With a right-handed screw, if the head of the aeroplane be turned to the left, the horizontal rudder must be inclined to prevent the rear part of the machine from sinking. The inclination of the propeller shaft does not affect these results, so that, so long as the turning couple is constant, so long will the tendency to precess be unchanged; if, however, the revolutions of the propeller be reduced, the rate of precession will increase.

In the Aeroplane Show at Paris this year, the most notable machine from the point of view of inherent longitudinal stability was one designed by M. Drzewiecki, who read a paper before this Institution in 1901. The principle embodied in this design is that of difference in pressure intensity on the forward and the after curved planes, due to the different cross-sections. On the involuntary rising of the fore part of the machine, the increase in the angle of attack has quite a different effect on the fore to what it has on the rear plane. The pressure per square foot on the front plane is but very gradually increased for changes of the angle of attack between the limits of 5° and 18°, whereas that on the after plane increases very rapidly with the angle at which the wind meets it. The result is an excess of lift aft which restores the machine to its original position. The converse holds if the front of the machine is involuntarily depressed. The reduction in the angle of attack leaves the pressure on the front plane but slightly altered, but reduces quickly that on the rear plane, resulting in a drop of that part to the normal position.

TIMING GEAR FOR THE ADMISSION OF LIQUID FUEL IN OIL ENGINES.

THE accompanying illustrations show an arrangement of timing gear, the invention of Mr. James McKechnie, of Vickers, Ltd., Naval Construction Works, Barrow-in-Furness, by means of which the period of admission of liquid fuel in internal-combustion engines of the Diesel type may be varied at will during the running of the engine by the adjustment of the position of the valve-operating cam. It is intended more especially for use in connection with an engine of the kind in which the liquid fuel is injected suddenly into the cylinder under extremely high resilient pressure. In such an engine the accurate timing of the fuel admission is of considerable importance, different periods being required for efficient working at high or low engine speeds, or at high or low powers for the same speed.

Fig. 1 is an elevation of the gear, Fig. 2 is a view at right angles to Fig. 1, and Fig. 3 is a sectional detail of the coupling device employed. A is a shaft through which the fuel cam shaft B is driven from the cam shaft C controlling the suction and exhaust valves. D is the coupling element mounted to slide on the shaft A and to turn with it, this element being in the form of a nut with internal spiral teeth J. E is the driven element of the coupling, driving the fuel cam shaft B through bevel wheels K L, and having spiral teeth M meshing with the teeth J of the nut D. F is a sliding sleeve through which the longitudinal adjustment of the nut D is effected, ball thrust bearings being interposed between the nut and sleeve. The timing gear is carried by the casing G forming part of the frame of the engine. The bevel wheel K on the horizontal fuel cam shaft B gears with the bevel wheel L on the upper end of the coupling element E which forms a continuation of the vertical driving shaft A. The sliding sleeve F is connected through bolts to a collar N which is engaged by the fork O forming an arm of the bell crank lever

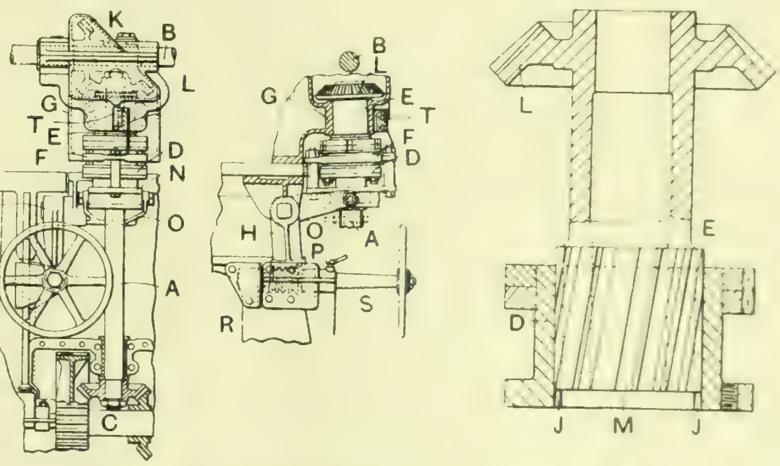


FIG. 1. FIG. 2 FIG. 3.
TIMING GEAR FOR OIL ENGINES

H, the other arm of which is in the form of a toothed segment P gearing with the worm R on the shaft S turned by the hand wheel shown. On rotating this wheel the lever H is slowly turned around its axis and the sleeve F is moved up or down, giving to the coupling member D, through one of the ball thrust bearings, a corresponding axial movement with relation to the shaft A. This axial movement, acting through the spiral teeth J and M of the two coupling elements D and E, causes the latter element to turn through an angle (relatively to the element D) which depends on the axial displacement and on the slope of the teeth J and M. The phase of the movement of the fuel cam shaft with relation to that of the engine crank is altered by a corresponding angle through the bevel gearing K L. After adjustment the hand wheel may be fixed in position by means of a small binding screw. The apparatus is arranged to give adjustment to the cam through an angle of about 30° to 40° and the angle of adjustment of the fuel cam shaft and consequently the timing of the fuel valve is indicated by the pointer on the sleeve F moving over the fixed graduated plate T.

A COMPARATIVE TRIAL BETWEEN THE TRIPLE EXPANSION ENGINE AND GEARED TURBINES IN CARGO STEAMERS.*

BY C. WALDIE CAIRNS, M.SC.

(Concluded from page 419.)

REGARDING the trials, it is a matter of regret to the author that no "measured mile" results are available for either of the ships in question, in either light or loaded condition. Neither of them have been "on the measured mile" off the Tyne. There is none available in the Bristol Channel, and the nature of tidal currents there makes any attempt at exact speed determination by distance run point to point practically useless, whilst in the English Channel the weather conditions were too unfavourable to make any useful record obtainable. It will be understood that the object of the trials to be described was purely a comparison of the two ships under conditions as nearly identical as could be attained. With this end in view the two steamers loaded to draughts mentioned, left Cardiff Docks on the morning tide of Thursday, February 6th, 1913. The Parsons Marine Steam Turbine Company, Ltd., Messrs. Wm. Doxford & Sons, Ltd., and Messrs. Cairns, Noble, & Co., managers of The Cairn Line, each had three watches of observers on each steamer. The owners were particularly concerned in the coal records, but the two first-mentioned firms in addition to checking coal consumption, obtained other records of particular interest from their respective standpoints, and by their courtesy, the author is enabled to embody them in this paper. The two ships were run by their usual staffs of engineers and firemen, the only additional assistance in stokehold being one man on each watch for the filling of coal skids.

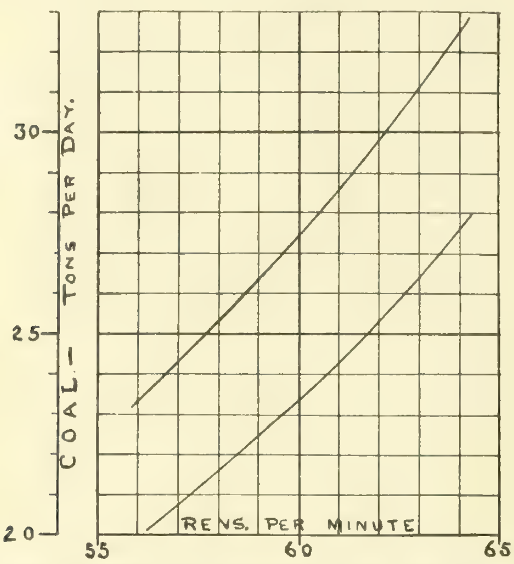


FIG. 7.—ESTIMATED PERFORMANCE IN FINE WEATHER.
Upper curve, s.s. "Cairngowan"; Lower curve, s.s. "Cairnross."
Trim of ships and evaporation as on 36 hour trial.
Note.—60 revs. per min. corresponds (approx.) to 10 knots.

On completion of compass adjusting, &c., the two vessels left Barry Roads about 4 p.m. on February 6th. It had been arranged that the coal measuring trial would commence at some time the same night, time to be agreed by exchange of signals after steady working of firemen and steady steam was assured. Instructions had been given for 62 revs. to 63 revs. to be aimed at, and for the vessels to be kept constantly within signalling distance of one another. Before settling to steady running, a series of records were taken on the "Cairnross" which may be described in one sense as a "progressive trial." These were taken just after leaving Barry Roads, in comparatively fine weather conditions, for the purpose of obtaining a curve connecting revolutions per minute, with steam pressure at entrance to turbine at this draught and trim of the ship. The results of this trial are embodied in the lowest curve in Fig. 7. It will be noticed on this curve that spots, representing actual readings, show recorded results at from 56 to 64·2 revs. per minute. A use for this curve will be referred to later.

* Paper read before the North-east Coast Institution of Engineers and Shipbuilders, March 28th, 1913.

As the ships proceeded down the Bristol Channel the weather freshened, and a strong head wind and sea was encountered by the time both ships were ready for coal measuring. The revolutions were therefore allowed to remain at from 60 to 62, the horse-power under these weather conditions, at 63 revs., being heavy, and not representing anything like normal running conditions for either ship. At 9 p.m. Thursday (February 6th), coal measuring commenced on each ship, both being then in the neighbourhood of Lundy Island. The vessels proceeded around Land's End, up the English Channel as far as St. Catherine's (Isle of Wight), where both vessels "put about" and back towards Brixham. Coal measuring ceased at 9 a.m. Saturday (February 8th), thus allowing a continuous record for 36 hours, and Brixham was reached about noon.

From the log abstracts appended, it will be seen that stormy weather was experienced throughout the trial. As the wind and sea were abeam only for a short time whilst rounding Land's End, being ahead, or abaft the beam the remainder of the time, no difficulty in keeping steam arose from rolling. In considering the results obtained in this trial, it must be borne in mind that ordinary seagoing conditions of running were adhered to. Thus steering engine, steam ash hoist, and auxiliaries were supplied with steam from the main boilers. The evaporator, too, was run in each case as necessary watch by watch, for the maintenance of water level in boilers. Steam was also supplied to radiators in officers' quarters and to steam boiler in galley. No correction has been applied for these items. Further, fires were burned down, cleaned, and made up as in ordinary running on voyage. The author understands that this is not always done in consumption trials, especially in cases where forced draught is available, and, naturally, where such procedure becomes possible, through shortness of trial or other cause remarkably favourable results may be obtained which could not possibly be maintained on a more extended trial. Further, in view of the careful and frequent determination of horse-power, any inflated figures are avoided such as are often put forward in steamship reports in which indicator cards, obtained when conditions are at their most favourable level in the day's work, are coupled with the coal consumption over the whole of a 12 hours' or 24 hours' trial. Anyone who has practical experience of the running or supervising of

TABLE II.—*Summary of 36-Hour Trial.*

	"Cairnross" Geared turbine.	"Cairngowan" Triple expansion.
1. Revolutions per min. (mean of 36 hour)	61·76	61·68
2. Coal per day	27·8 tons	32·7 tons
3. I.H.P.	—	1,790
4. S.H.P.	1,570	—
5. Ratio of S.H.P. "Cairnross" to I.H.P. of "Cairngowan"	87·7%	—
6. Lbs. of coal per I.H.P hr. all purposes........	(equiv.) 1·45 lbs.	1·704 lbs.
7. Lbs. of coal per S.H.P. hr. all purposes......	1·65 lbs.	(equiv.) 1·94 lbs.
8. Estimate of water consumption per hour all purposes	22,000 lbs.	27,200 lbs.
9. Estimate of water consumption per I.H.P. hour	(equiv.) 12·3 lbs.	15·18 lbs.
10. Estimate of water consumption per S.H.P. hour	14 lbs.	(equiv.) 17·3 lbs.
11. Hot well temperature..	79° Fah.	104° Fah.
12. Feed temperature......	203° Fah.	221° Fah.
13. Estimate lbs. of water per lb. of coal (from feed temperature) ..	8·5 lbs.	8·97 lbs.
14. Percentage of ash......	12·5%	9·36%
15. Pressure, steam pipe in engine room	158 lbs.	175 lbs.
16. Initial pressure, H.P. turbine	138 lbs.	—
17. Vacuum	28·75″	26·8″
18. Circulating water inlet..	50° Fah.	50° Fah.
19. ,, ,, outlet	70° Fah.	95° Fah.

steamers is well aware of the caution with which reports must be accepted, in which claims are made regarding triple-expansion machinery alleged to be able to do their daily work at from 1·2lbs. to 1·5lbs. of coal per indicated horse-power hour. Shipowners and engine builders alike appear to enjoy tall tales of this order, but in this case the author has no such tale to tell. General results of the trial are given in Table II.

The main result in which the owners of the two ships, and no doubt other shipowners, are interested is the ascertained coal per day of the two ships, 32·7 tons for the triple expansion set and 27·8 tons for the geared turbine set, a gain of 15 per cent. of the consumption of the triple set, or stated in the other direction, the triple set demands 17·6 per cent. more fuel than the turbine set. Referring to the other comparisons in Table II., the following explanations and comments are offered :—

Line 1: Revolutions per minute were ascertained by a mechanical counter.

Line 2: Coal per day. The coal for the whole period of trial was measured by means of the usual stoke-hold skids—open-bottomed measures of sheet iron. The weight of the contents of representative skids were taken each watch, and the coal used on each watch was calculated from the weight per skid taken during that watch.

Line 3: The indicated horse-power on the "Cairngowan" has been calculated from the cards by planimeter in the usual way, no deduction being made for piston rod areas. A typical set of indicator cards is shown in Figs. 8, 9, and 10.

Line 4: The shaft horse-power on the "Cairnross" was obtained by a Hopkinson Thring Torsion meter, applied to a calibrated length of shafting in tunnel, and is therefore practically the effective power supplied to the propeller.

Line 5: Ratio of shaft horse-power of "Cairnross" to indicated horse-power of "Cairngowan." This gives an interesting approximate determination of the mechanical efficiency of such a set of triple expansion machinery, including thrust block. It seems safe under the circumstances of the trial to assume that the effective horse-powers of the two sets of machinery were equal.

Line 6: The "equivalent" figure 1·45lbs. given in "Cairnross's" column may be taken to mean the coal per indicated horse-power hour that a reciprocating set under similar circumstances and with same boiler efficiency would have to attain to give results equal in coal economy to the results on the turbines. The actual figure for the triple—1·704lbs. per indicated horse-power hour—appears high in view of the efficient feed heating; but the fact that the result includes coal for all purposes must be borne in mind, as well as certain points regarding evaporation to be referred to later on. It will be noticed from the indicator cards that the engines of the "Cairngowan" are well-loaded, the "referred mean pressure" being nearly 37½lbs. per square inch. This is probably not conducive to a good result in fuel per indicated horse-power hour, although favourable to true economy in fuel per effective horse-power hour.

Line 7: For the "Cairnross" this figure is the direct result of lines 2 and 4. For the "Cairngowan" this figure is obtained on the assumption that the shaft horse-powers of the triple and turbine sets are equal.

Line 8: In the case of the "Cairngowan" the single Weir's pump delivering hot feed from heater to boilers was utilised as a water meter, the number and the length of its strokes being integrated by a mechanical counter, and a delivery efficiency of 90 per cent. being assumed. As the auxiliary exhausts including exhaust from steering engine mingle with the water from main engine feed pumps in the feed heater, the water measured by the Weir feed-pump is really the total consumption of main and auxiliary machinery, and should represent the total evaporation of the boilers. This figure is, of course, subject to the uncertainty involved in the assumption above as to the "slip" of the pump.

The figure given for the "Cairnross," in line 8, is the turbine consumption calculated from the average pressure at first stage in turbine, and from area through blades of first guide row in accordance with experimental results in Messrs. Parsons' possession, plus an allowance for exhaust from auxiliaries, calculated from the observed rise of temperature resulting from the mixture of this exhaust steam with the condensed exhaust from turbine. The calculation has been made on the basis of dry saturated exhaust from the auxiliaries, which probably introduces an error reducing the calculated total below its true value—for instance, a dryness fraction of the auxiliary exhaust steam of ·5 would nearly double the allowance for auxiliary exhausts, raising the water per hour to about 24,400lbs. Probably the true value lies between this and 22,000lbs. An attempt was made to measure the feed water by the pump counter in the case of the "Cairnross," as in the "Cairngowan," but the slip of the pumps in the "Cairnross" proved to be so variable from hour to hour that there was no option but to discard the results, and fall back on an estimated value.

Lines 9 and 10 are subject to interpretation similar to that indicated for lines 6 and 7, with the reservation that lines 5 and 6 represent the results of actual measurements, assumptions such as are mentioned in connection with line 8, from which lines 9 and 10 are calculated, not being involved in lines 2, 6, and 7.

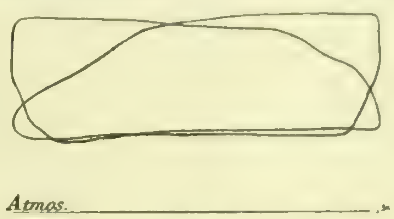


FIG. 8.
H.P. diagram. M.E.P. 80·6lbs. per sq. in. I.H.P. 512. Scale $\frac{1}{8}$in. = 80lbs.

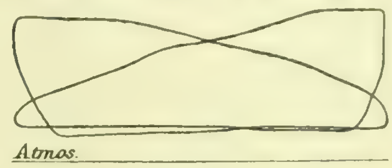


FIG. 9.
I.P. diagram. M.E.P. 34lbs. per sq. in. I.H.P. 598. Scale $\frac{1}{8}$in. = 40lbs.

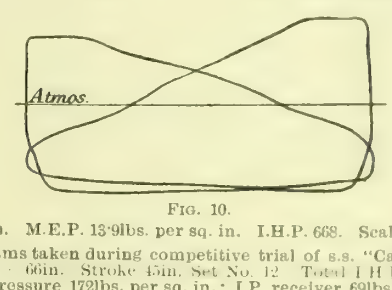


FIG. 10.
L.P. diagram. M.E.P. 13·9lbs. per sq. in. I.H.P. 668. Scale $\frac{1}{8}$in. = 12lbs.

Indicator diagrams taken during competitive trial of s.s. "Cairngowan." Cylinders 24in. × 40in. × 66in. Stroke 45in. Set No. 12. Total I.H.P. 1778. Revs. per min. 62; boiler pressure 172lbs. per sq. in.; I.P. receiver 69lbs. per sq. in.; L.P. receiver 13·75lbs. per sq. in.; vacuum 26⅞ins.

Line 11: The hotwell temperature in the case of the "Cairnross" is measured in the head of the wet air-pump.

Line 12: The feed temperature mentioned in case of "Cairnross" was attained by utilisation of auxiliary exhaust only. This rise of temperature amounting to 123° is, of course, a valuable aid to economy of fuel, representing as it does the return to the boiler of the latent and sensible heat of the auxiliary exhaust. The author thinks he will be correct in claiming this as the first instance of the installation of a contact heater with turbine machinery. In the case of the "Cairngowan," less auxiliary exhaust is available, but by the aid of steam withdrawn from the lower-pressure steam chest, the very satisfactory temperature mentioned is maintained, and the feed pump deals with the water at this temperature without any difficulty.

Line 13: Estimate "lbs. of water per lb. of coal." This is the result of calculation based on the measured quantities of line 2, and the estimated quantities in line 8. It is thus an estimated evaporation "from feed temperature at boiler pressure." Converted to "evaporation from and at 212°" the figures would be about 5 to 6 per cent. greater. There seems no obvious reason why—with identical boilers—there should be nearly 5 per cent. poorer evaporation in the case of the "Cairnross" than in the "Cairngowan," the only apparent difference in conditions being the 15 per cent. lower

demand for steam, which could hardly raise the boiler radiation-loss ratio high enough to reduce the efficiency to this extent. Part of the apparent difference is no doubt traceable to the different means of ascertaining the water consumption in the two cases. If the evaporation for the "Cairnross" be calculated on a mean between the water consumption stated in Table II. and the figure based on ·5 dryness of auxiliary exhausts, say 23,200lbs. per hour, the evaporation comes to practically the same figure as on the "Cairngowan." In neither case can the evaporation per pound of coal be considered very good, in view of the fact that a good class of Welsh coal was used, of "Admiralty large" type. The coal burnt per square foot of grate (neglecting the bridges) works out to 17·91lbs. per hour for the "Cairnross," and 21lbs. per hour for the "Cairngowan." Owing to the high funnels, the draught was always ample; probably with such ample draught a more economical result would have been attained with either smaller tubes or with retarders in the actual tubes. It should be stated that in spite of the apparently high percentage of ash, and the fairly high rate of combustion, there was no difficulty in keeping good fires; no pricking and only one turn with a round poker was necessary between each

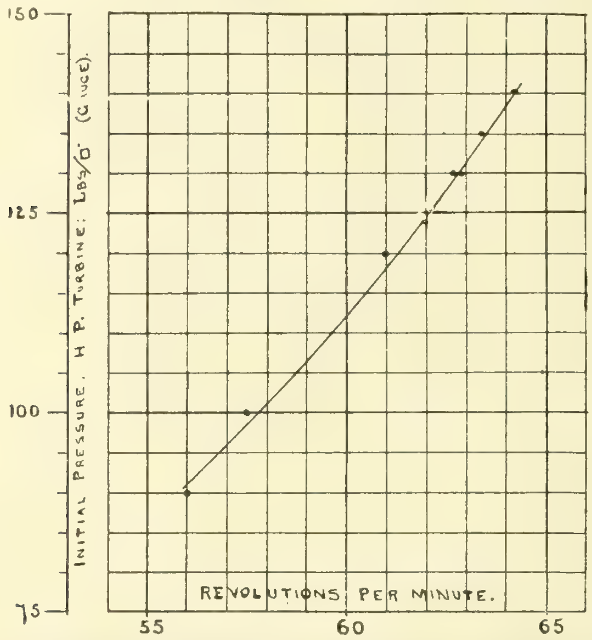


FIG. 11.—RESULTS OF PROGRESSIVE TRIAL (SMOOTH WATER) S.S. "CAIRNROSS."

round of firing; at the same time it is possible that better results might have been obtained with good North-country coal which, according to the writer's experience, is usually at least as satisfactory as Welsh coal with natural draught and the usual firemen obtainable.

Line 14: Percentages of ash. The difference between the results on the two ships is possibly due to some difference in the incidence of fire cleaning, as the coal for the two ships was got from the same colliery.

Line 17: In the "Cairnross" the vacuum was measured by the "Kenotometer," an instrument by which the absolute back-pressure is indicated by a mercury column, so arranged that it is practically impossible for any accident to cause mercury to be drawn to the condenser. It is not perhaps generally enough realised that mercury has a prompt and ruinous effect on the metals and alloys usually classed as "non-ferrous." The Kenotometer was connected to the upper part of the condenser, at its forward end. On the "Cairngowan" an ordinary Bourdon type vacuum gauge was connected to a point just below the centre of the condenser, at the forward end.

The weather conditions during this trial make direct comparison of the running on trial of these two ships with the ordinary running of any other ship useless. The immediate object of the trial was obtained, namely, a comparison of the two ships under identical conditions. The law of steam consumption of the steam turbine, however, makes some interesting deductions from the rough weather trial possible. The law is an experimental result, well founded in Messrs. Parsons' experience, to the effect that in a given turbine (with constant vacuum) the steam passed per unit of time is approximately proportional to the absolute pressure at inlet to high-pressure turbine, and is practically independent of the speed of rotation. It follows, therefore, that the inlet-pressure gauge is a reliable index of the consumption of steam, and consequently of fuel. The "revolutions per minute" of the system, for a given initial pressure, will, of course, vary with each change of turning moment resistance, as altered by the variations of resistance of the ship, and the consequent variations of thrust and slip.

As the "Cairnross" was at same draught on the smooth water trial and on the 36-hours' trial, the law above enables a connection between the two trials to be established as follows: It was found on 36-hours' trial, that to maintain 138lbs. initial pressure (or rather steam flow resulting from same) a consumption of 27·8 tons of coal per day was required. Owing to weather conditions, the revolutions per minute on this trial were only about 61·8. On referring to Fig. 11, where steam-pressure and revolution per minute for smooth water conditions are plotted, we find that 138lbs. initial pressure should give 64 revs. per minute in smooth water. We may therefore safely deduce that for 64 revs. per minute, in smooth water, with the ship in trial trim, the consumption of coal would be 27·8 tons per day. On Fig. 7 this deduction, 64 revs. per minute, for 27·8 tons per day, is used as the starting point for a new curve, the lower of the two, connecting coal per day and revolutions per minute for the "Cairnross." Of course, this 27·8 tons per day includes coal for auxiliaries, so in extending the curve to lower revolutions the following assumptions are made. (1) That the initial pressure and revolution will be connected as on Fig. 11. (2) That the turbine consumption will be proportional to the absolute initial pressure. (3) That the auxiliary steam will be constant (calculated as before with dryness fraction = 1). (4) That the coal per day will be proportional to the turbine steam and auxiliary steam, with total coal 27·8 tons per day for 64 revolutions per minute as basis.

In attempting to extend the "Cairngowan's" 36-hours' trial result to smooth water conditions we are met with difficulties arising from change of feed per revolution and change of revolutions, between the trial figure 61·8 and the standard 64 revolutions, with their unknown effect on consumption. If we assume, however, that the same effective horse-power is required in the two ships, at the 36-hours' trial condition and at 64 revs. in smooth water—and this only involves the assumption of constant efficiency of the turbines from 61·7 revs. per minute to 64 revs. per minute—we may claim that in the case of the "Cairngowan" 32·7 tons per day should give 64 revs. per minute in smooth water.

If we assume further that the ratio ascertained on trial between the consumptions of the two ships at trial conditions (assumed also for 64 revs. smooth water conditions), holds within the limits of Fig. 7, we can plot the upper curve on that figure. This curve agrees fairly well with the ordinary running results of the "Cairngowan" at about 60/62 revs. per minute. Of course, any improvement in evaporative efficiency would improve both ships proportionately.

In conclusion, the writer must express his indebtedness to The Parsons Marine Steam Turbine Company, Ltd., and to Messrs. Wm. Doxford & Sons, Ltd., for the use of plans and trial records, and to them and the owners of the two ships for permission to make public the results obtained.

APPENDIX.

Extract from Chief Officer's Log Book, s.s. "Cairngowan."

Thursday, February 6th.

2-45 p.m. Arrived Barry Roads, turned round and proceeded at half speed. 3 p.m., full speed.

6-5 p.m. Nash point abeam.

8 p.m. Strong gale, head sea, vessel shipping water forward—clear.

9 p.m. Started trial.

10-55 p.m. Hartland Light abeam, distance 5ft.

12 p.m. Strong gale and terrific squalls, high sea, vessel plunging heavily, clear.

Friday, February 7th.

2-50 a.m. Trevose Head abeam, distance 7ft.

4 a.m. Moderate gale and high head sea; vessel flooding fore decks and hatches; clear weather.

8 a.m. Longships abeam, distance 1in.
10-35 a.m. Lizards abeam, distance $3\frac{1}{2}$ft.
Noon. Moderate to fresh gale, heavy beam sea, vessel taking quantities of water fore and aft, misty rain.
4 p.m. Similar weather continues.
8 p.m. Strong gale, very high sea, vessel taking large quantities of water, weather clear at times.
9-41 p.m. Portland abeam, distance $9\frac{1}{2}$ft.
11-10 p.m. Anvil Point abeam, distance 9ft.
Midnight. Strong following breeze and sea, clear

Saturday, February 8th.

1-45 a.m. St. Catherine's abeam, distance 6ft. Turned ship round and proceeded to Tor Bay.
4 a.m. Strong half gale with terrific squalls, and clear.
4-25 a.m. Anvil Point abeam.
7-8 a.m. Portland abeam, distance 5ft.
8 a.m. Strong head wind and sea; vessel flooding fore deck and hatches, clear weather.
9 a.m. Finished trial.

CASE-HARDENING OF GEARS.

IN the discussion on the paper on "Case Carbonising," by Mr. M. T. Lothrop, read before the American Society of Mechanical Engineers, Mr. B. E. Bisler, of the Cambria Steel Company, furnished some interesting information relating to the case-hardening of parts in the works of his firm. About 700

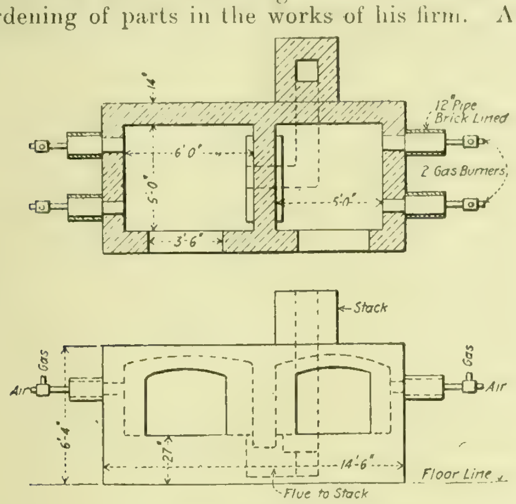


FIG. 1.—FURNACE FOR CASE-HARDENING.

or 800 bevel and spur gears for mill roller runs had, he mentioned, been treated during the past three years, varying in size from 10in. to 18in. pitch diameter and about 4in. to 5in. width of face. Practically all crane and motor pinions were now case-hardened and a few spur gears as large as 30in. diam. by 8in. face had been treated. About 90 per cent. of the case-hardened gears were made from open-hearth steel

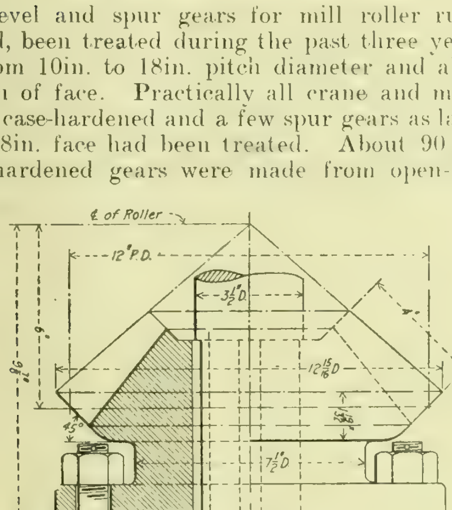


FIG. 2.—HALF COUPLING WITH MITRE GEAR. No. 1 MILL FURNACE RUN; 0·12 PER CENT. CARBON STEEL; CASE CARBONISED ON FACE AND IN BORE AND KEY WAYS. PENETRATION, $\frac{1}{8}$IN

forged blanks of dead soft stock with carbon between 0·08 and 0·12 per cent. The company had case-hardened steel with a carbon content as high as 0·20 per cent., but found that the best results were obtained by using steel with carbon under 0·12. The other 10 per cent. of the gears treated were steel castings made to the following specifications: carbon 0·10 to 0·15 per cent.; sulphur, not over 0·05 per cent.; phosphorus, not over 0·04 per cent.; silicon, 0·15 to 0·30 per cent.; and manganese, 0·60 to 0·80 per cent.

Regarding the life of the case-hardened gears, he stated that the roller run was installed in front of mill furnace No. 1 about four years ago, when about 200 case-hardened gears were used, and up to the present not one had been replaced, although the table had seen very hard service. Gears in the

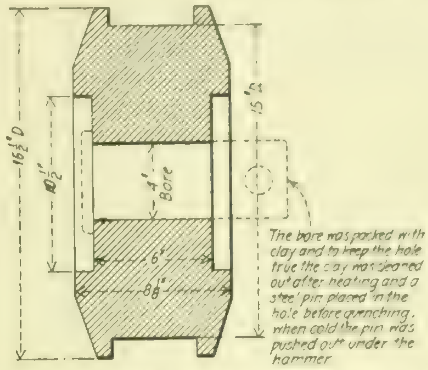


FIG. 3.—CASE-HARDENED ROLLER FOR ORE SCREENING PLANT.
About 30 hours is required for [illegible] in. penetration.

roller runs leading up to the 18in. mill, in the roller runs at Gautier 24in. mill, and in the tables at the Franklin Mills, were giving equally good service. Among other parts case-hardened were bushings for roller bearings (ground after treated); links and chains for conveyer chains (very light penetration, about $\frac{1}{64}$ in.); and valve motion parts and connecting rod slides for locomotive repairs.

The gears or other parts to be treated were placed in round or square boxes and packed with bone black, using about three-quarters old to about one-quarter new material. The boxes were then sealed with clay and placed in the furnace, where they were heated by natural gas to a temperature of about 1,800° Fah. The time required to heat properly varied from 12 hours to 30 hours, depending entirely on the size of the parts being treated and the amount of penetration desired. A great amount of the work required about 20 to 24 hours from the time the furnace was lighted until the charge was ready to be withdrawn and quenched. This would

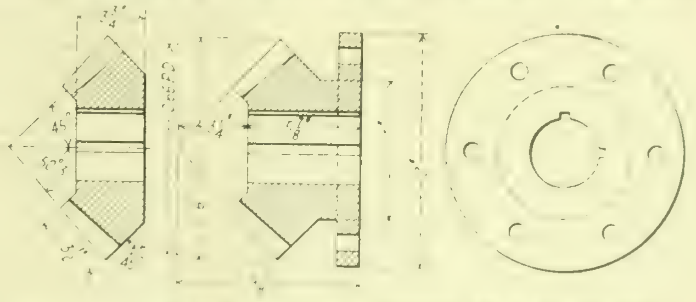


FIG. 4.—GEARS FOR 24IN. MILL TABLES; FORGINGS, 0·08 TO 0·12 PER CENT. CARBON STEEL.
About 24 hours required for $\frac{1}{8}$in. penetration.

give about $\frac{1}{8}$in. penetration, which was the depth reached on most of the gears.

On light work the charge was usually allowed to cool before it was taken out of the carbonising material, when it was reheated to about 1,400° Fah. and quenched in water. Nearly all of the gears and other heavy work were quenched in water direct from the packing box, a method which gave very good results and saved the cost of reheating. The heat in the gear at the time of quenching in this case was also 1,400° Fah. as near as the operator was able to judge with the eye. It was found necessary to grind the bores of all gears after hardening as the bore was usually slightly out of round. Boxes made of 1in. plate steel would last for about 15 times in the furnace before they became too thin from frequent scaling. The furnace used was of very simple construction, with two heating chambers, each being supplied with two natural gas burners. No trouble whatever was experienced in maintaining an even temperature of 1,800° Fah. throughout the time the charge was in the furnace. The time required to bring the cold charge up to this temperature required from four to six hours. A diagram of the furnace used is shown in Fig. 1, and drawings of the pieces case hardened in Figs. 2-4.

MODERN LOCOMOTIVE PRACTICE IN EUROPE AND AMERICA.*

BY LAWFORD H. FRY, M.INST.C.E.

THE present paper shows the most important types and sizes of locomotives which are being used by the principal railways of Europe and America, and gives an idea of the general trend of locomotive practice at the beginning of the year 1913. The railways having locomotives referred to in the paper are enumerated in Table I., which also shows the mileage and the total number of locomotives owned by each road. The European roads represented cover about 64,000 miles, and have about 60,000 locomotives, while the American roads, with about 57,000 miles, have about 15,000 engines. These railways represent about 30 per cent. of the total European mileage and about 26 per cent. of the total mileage in the United States, and though some important railways are omitted those included are sufficient in number and importance to represent good practice in the two continents. Similarly, the locomotives shown for each road do not represent exhaustively the practice of that road, but, taken as a whole, they give a reasonably good picture of modern tendencies of designs.

TABLE I.

Total Mileage and Total Number of Locomotives on Railways Mentioned in Paper.

Railway.	Total Mileage.	Total Number of Locomotives.	Locomotives for each 10 miles of Railway
Great Central	631	1,257	—
Great Eastern	1,217	1,085	—
Great Northern	1,008	1,279	—
Great Western	3,000	2,596	—
Lancashire and Yorkshire	597	1,549	—
London and North Western	1,966	3,063	—
London and South Western	1,022	748	—
London, Brighton, and South Coast	487	535	—
Midland	1,416	2,800	—
North Eastern	1,734	2,000	—
Caledonian	1,035	927	—
North British	1,357	906	—
Total (11 British Railways)	15,470	18,745	12·1
Belgian State	2,700	4,187	15·5
P.L.M.	6,310	3,291	—
French State	5,270	2,419	—
Nord	2,490	1,993	—
Paris-Orleans	4,520	1,902	—
Total (4 French Railways)	18,590	8,605	4·6
Prussian State (about)	21,000	20,000	—
Bavarian State	4,880	2,365	—
Baden State	1,090	836	—
Total (3 German Railways)	26,970	23,201	8·6
One Italian State	10,500	4,937	4·7
Atchison	5,562	1,706	—
Baltimore and Ohio	3,462	1,739	—
Burlington	9,074	1,661	—
Rock Island	7,449	1,500	—
Erie	2,430	1,448	—
G.N. (U.S.A.)	6,894	1,173	—
New York Central	3,320	1,940	—
Nashville	1,230	265	—
S. Pacific	6,663	1,326	—
Virginian	474	82	—
Wabash	2,524	650	—
Illinois Central	4,755	1,410	—
Chicago G.W.	1,471	323	—
Norfolk and Western	1,937	968	—
Total (14 American Railways)	57,235	15,194	2·7

The selection of representative locomotives for the various European roads has been left by the author in a large measure to the chief mechanical engineers of the railways. He asked a number of these gentlemen to give him particulars of (*a*) a modern passenger locomotive, and (*b*) a modern goods locomotive. For their courtesy in answering this enquiry the author wishes to express his sincere thanks. Information regarding the Belgian and Italian locomotives is taken from the account of locomotives at the Brussels Exhibition by Signor I. Valenziani, of the Italian State Railways, while the particulars of the Prussian State locomotives are from "Die Entwicklung der Lokomotiv-Parkes bei den preussisch-hessischen Staatseisenbahnen," by Gustav Hammer, and the particulars of the Paris-Orleans engines from articles in the "Revue Générale des Chemins de Fer," by MM. Paul Conte and Laurent. The American engines are selected from typical examples recently constructed by the Baldwin Locomotive Works, with the exception of the large Virginian Mallet, which was built by the American Locomotive Company.

The majority of the locomotives to be examined have separate tenders, and the particulars of all these engines are given in Table II. for goods and in Table III. for passenger service. In these tables the locomotives are arranged in order of total weight, and in addition to particulars as to the type of wheel arrangement, the quality of steam used, whether saturated or superheated, the number and dimensions of cylinders, and whether single expansion or compound, the diameter of driving wheels, and the boiler pressure, there are given for each engine the four important dimensions of total weight, weight on driving wheels, rated tractive effort, equivalent heating surface and grate area. These dimensions determine the service for which the engine is adapted. The weight on driving wheels, by which the author means the weight on all coupled wheels or adhesive weight, taken in conjunction with the rated cylinder tractive effort, determines the maximum pull the locomotive can exert. The rated cylinder tractive effort represents the maximum tractive force the cylinders can deliver at the rim of the driving wheels, and for the single-expansion engines is calculated by allowing a mean effective pressure of 85 per cent. of the boiler pressure. For compounds the rated tractive effort is calculated on the assumption that the work done in the high and low pressure cylinders is the same, and that the mean effective pressure in the high-pressure cylinder is $\frac{0 \cdot 9b}{1+b}$ P, where b is the ratio of the volume of the low-pressure to that of the high-pressure cylinder, and P is the boiler pressure. The heating surface determines the horsepower, and hence fixes the maximum pull that can be exerted at a given speed or the maximum speed that can be attained when exerting a given pull. Approximately 1 h.p. can be obtained from each $2\frac{1}{4}$ sq. ft. of equivalent heating surface. The figures given in the tables show the equivalent heating surface, that is to say, the amount of heating surface which in a saturated steam locomotive would give the same power as can be obtained from the superheater engine. This equivalent heating surface is obtained by adding to the evaporative surface $1\frac{1}{2}$ times the surface of the superheater. The grate area from its proportion fixes the rate of combustion, and hence the quality of fuel for which the engine is adapted.

Goods Engines.—Coming now to a general comparison, take first the goods engines of Table II. The first point to be remarked is the wide range of size. The total weights run from 100,000lbs. (45 tons) for the North British 0—6—0 to 540,000lbs. (240 tons) for the Virginian 2—8—8—2 Mallet. Between these extremes the locomotives fall more or less clearly into three groups according to nationality. At the lighter end are the British, and at the heavy end the Americans, while the continental engines take an intermediate position. The average American engine is about twice as heavy as the average British engine, while the heaviest American is over three times as heavy as the heaviest British, and over five times as heavy as the lightest British machine.

This very considerable difference between the practice on the two sides of the Atlantic is not determined by undue conservation on this side or by a tendency to exaggeration of the other. It is legitimately produced by the difference in the conditions of the traffic. Great Britain is densely populated, while in the United States the population is much more widely distributed, so that it is necessary to provide a considerably greater mileage for each inhabitant. The actual mileage is some ten times greater (220,000 to 22,000 miles in round figures), while the population is only about two and

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one-half times as great (say, 100,000,000 to 40,000,000), so that each inhabitant of the United States is served by about four times as much mileage as each Briton. Roughly speaking, Great Britain has about 1,800 inhabitants per mile of railway, and the United States about 450. From the longer haul thus necessitated, and from the large quantities of raw material to be handled, it follows that, while in England it is economical to provide an intensive service with a large number of trains of moderate weight, in the United States, less frequent and much more heavily-loaded trains give more economical results. These conditions of operation are also reflected in the number of locomotives per mile of road. On the railways mentioned in this paper the English roads have for each 10 miles of road 12·1 engines, while the American roads have only 2·7 engines. The same influences are visible in the continental countries. Belgium and Germany are densely populated, and show comparatively large numbers of light locomotives per mile of road, while more sparsely populated France employs fewer and heavier engines.

Consider now the types, or wheel arrangements, employed in goods service. Table II. shows the number of engines of each type belonging to the various countries. From a consideration of this, the various types may be characterised as follows: —

0— 6—0 ... Light goods ....British.
2— 6—0 ... Fast goods ....British.
4— 6—0 ... Express goods ....British and French.
0— 8—0 ... Heavy goods ....British and German.
2— 8—0 ... Heavy goods ....British and continental.
4— 8—0 ... Heavy fast goods ....French.
0—10—0 ... Heavy goods ....Continental.
2—10—0 ... Heavy goods ....Continental.
2— 8—2 ... Heavy goods ....American.
2—10—2 ... Extra heavy goods ....American.
Mallet ...... Extra heavy goods ....American.

TABLE II.

Goods Locomotives.

Railway.	Class.	No. of Cylinders.	Single Exp. or Comp.	Saturated or Super.	Cylinder Diam. and St. Ins. Ins.	Driving Wheel Diam. Ins.	Boiler Pressure Lbs. per sq. in.	Total Weight. Lbs.	Weight on Drivers Lbs.	Tractive Effort. Lbs.	Equiv. Heating Surface Sq. ft.	Grate Area Sq. ft.
Great Eastern	0– 6–0	2	S.E.	Super.	20 × 28	59	160	106,120	106,120	25,800	1,614	21·6
Midland	0– 6–0	2	S.E.	Super.	20 × 26	63	160	109,900	109,900	22,500	1,639	21·1
North British	0– 6–0	2	S.E.	Sat.	18½ × 26	60	180	112,950	112,950	22,600	1,748	19·8
Caledonian	2– 6–0	2	S.E.	Super.	19½ × 26	60	160	121,410	103,040	22,400	1,590	20·6
Prussian State	0– 8–0	2	S.E.	Super.	23·6 × 26	53	170	123,400	123,400	34,200	2,120	24·8
London and North Western	0– 8–0	2	S.E.	Super.	20½ × 24	53½	160	135,000	135,000	27,000	2,340	23·6
Great Northern	8– 6–0	2	S.E.	Super.	20 × 26	68	170	138,210	115,810	22,100	1,571	24·5
London, Brighton & South Coast	2– 6–0	2	S.E.	Super.	21 × 26	66	170	141,120	120,960	25,100	1,712	24·8
North Eastern	0– 8–0	2	S.E.	Super.	20 × 26	55¼	160	147,600	147,600	25,600	2,187	23·0
Lancashire and Yorkshire	0– 8–0	2	S.E.	Sat.	20 × 26	54	180	149,630	149,630	29,500	2,455	25·6
French State	4– 6–0	2	S.E.	Super.	21·6 × 25·2	69	170	152,400	113,700	24,800	2,144	29·9
Prussian State	0–10–0	2	S.E.	Super.	24·8 × 26	55	170	156,000	156,000	41,800	2,510	28·0
North Eastern	4– 6–0	2	S.E.	Super.	20 × 26	73¼	160	158,000	119,390	19,300	2,638	23·0
P.L.M.	4– 8–0	4	Comp.	Super.	$\left.\begin{matrix}15{\cdot}0\\23{\cdot}6\end{matrix}\right\}\times 25{\cdot}6$	59	228	154,000	124,600	28,500	2,579	33·1
Great Central	2– 8–0	2	S.E.	Super.	21 × 26	56	160	161,300	145,600	27,800	2,208	26·0
P.L.M.	2– 8–0	4	Comp.	Super.	$\left.\begin{matrix}15{\cdot}7\\22{\cdot}8\end{matrix}\right\}\times 25{\cdot}6$	59	228	161,700	140,000	29,000	2,150	32·0
Baden State	2– 8–0	4	Comp.	Super.	$\left.\begin{matrix}15\\24\end{matrix}\right\}\times 25{\cdot}2$	53¼	228	163,000	136,200	31,300	2,798	38·1
Paris-Orleans	2– 8–0	4	Comp.	Sat.	$\left.\begin{matrix}16{\cdot}1\\24{\cdot}4\end{matrix}\right\}\times 25{\cdot}6$	61	228	164,200	146,200	30,900	2,577	33·4
Italian State	0–10–0	4	Comp.	Sat.	$\left.\begin{matrix}14{\cdot}8\\24{\cdot}0\end{matrix}\right\}\times 25{\cdot}6$	53¼	228	165,000	165,000	31,200	2,392	37·7
Bavarian State	0–10–0	4	Comp.	Super.	$\left.\begin{matrix}16{\cdot}1\\25{\cdot}6\end{matrix}\right\}\times\left\{\begin{matrix}24{\cdot}0\\25{\cdot}2\end{matrix}\right.$	50	228	173,000	173,000	38,850	2,976	39·8
Nord	2– 8–0	4	Comp.	Super.	$\left.\begin{matrix}16{\cdot}5\\22{\cdot}4\end{matrix}\right\}\times\left\{\begin{matrix}25{\cdot}2\\27{\cdot}6\end{matrix}\right.$	61	228	181,200	159,400	30,700	3,019	34·6
Paris-Orleans	2–10–0	4	Comp.	Super.	$\left.\begin{matrix}18{\cdot}1\\26\end{matrix}\right\}\times\left\{\begin{matrix}24{\cdot}4\\25{\cdot}6\end{matrix}\right.$	55¼	228	187,600	171,500	40,800	3,005	40·9
Nord	2–10–0	4	S.E.	Super.	$\left.\begin{matrix}21{\cdot}6\\20{\cdot}9\end{matrix}\right\}\times\left\{\begin{matrix}25{\cdot}2\\27{\cdot}6\end{matrix}\right.$	61	170	216,500	194,000	56,600	3,714	34·6
Nord	2–10–0	4	Comp.	Super.	$\left.\begin{matrix}19{\cdot}3\\26{\cdot}8\end{matrix}\right\}\times\left\{\begin{matrix}25{\cdot}2\\27{\cdot}6\end{matrix}\right.$	61	228	218,000	194,500	42,700	3,714	34·6
Belgian State	2–10–0	4	S.E.	Super.	19·7 × 23·6	57	200	230,000	193,600	54,200	3,545	54·9
Wabash	2– 8–2	2	S.E.	Sat.	25 × 30	64	200	262,700	202,800	49,800	4,473	63·0
Burlington	2– 8–2	2	S.E.	Super.	27 × 30	64	170	271,000	207,000	49,300	4,926	54·2
Baltimore and Ohio	2– 8–2	2	S.E.	Sat.	24 × 32	64	205	274,600	219,000	50,200	5,017	70·0
Chicago G.W.	2– 8–2	2	S.E.	Super.	27 × 30	63	185	283,100	217,900	54,600	5,425	70·0
Illinois Central	2– 8–2	2	S.E.	Super.	27 × 30	63	175	283,850	218,300	51,600	5,388	70·0
Virginian	2– 8–2	2	S.E.	Super.	26 × 32	56	185	297,500	229,600	60,800	5,724	57·0
Rock Island	2– 8–2	2	S.E.	Super.	28 × 30	63	180	318,900	243,200	57,200	5,621	63·0
Erie	2– 8–2	2	S.E.	Super.	28 × 32	63	170	322,000	237,000	57,500	5,517	70·0
Burlington	2–10–2	2	S.E.	Super.	30 × 32	60	175	378,700	301,800	71,000	6,616	88·0
South Pacific	2–6–6–2	4	Mallet	Sat. (*a*)	$\left\{\begin{matrix}25\\38\end{matrix}\right\}\times 28$	63	200	384,800	320,000	69,800	5,793	70·0
Atchison	2–6–6–2	4	Mallet	Super. (*a*) (*b*)	$\left\{\begin{matrix}24\\38\end{matrix}\right\}\times 28$	69	220	390,200	319,000	66,200	4,554	63·0
Virginian	2–8–8–2	4	Mallet	Sat. (*a*) (*b*)	$\left\{\begin{matrix}26\\40\end{matrix}\right\}\times 32$	56	210	448,800	405,400	102,500	5,493	84·0
G.N. (U.S.A.)	2–8–8–0	4	Mallet	Super.	$\left.\begin{matrix}28\\42\end{matrix}\right\}\times 32$	63	210	450,000	419,000	104,000	7,091	78·4
Virginian	2–8–8–2	4	Mallet	Super.	$\left.\begin{matrix}28\\44\end{matrix}\right\}\times 32$	56	200	540,000	479,200	115,000	7,510	99·2

(*a*) Feedwater Heater. (*b*) Reheater.

Of these, the engines without trucks, the 0—6—0, the 0—8—0, and the 0—10—0 types, do not differ from each other in principle. The whole weight of the engine is carried on the coupled axles, and the choice between the three types will be determined by the adhesive weight required, and by the weight allowed on each axle. The other types are derived from these three by the addition of a truck or trucks. The addition of a two-wheeled front truck, giving the 2—6—0, 2—8—0, or 2—10—0 type, allows a larger boiler,

which makes for greater speed with the same weight on the coupled wheels. The front truck also has the advantage of relieving the wear on the flanges of the front pair of drivers when curves are encountered. The four-wheeled front truck is useful for higher speeds, as it gives a greater boiler capacity and steadier riding. For express goods service the 4—6—0 type is used particularly in England. The 4—8—0 is occasionally employed on the Continent, but has less justification, as a two-wheeled truck is well adapted to all speeds at which an eight-coupled engine is likely to be run.

The axle loads carried with the goods engines are about 15 tons in Germany and Italy, 17 tons in England, Belgium, and France, and 23 to 27 tons in the United States. This 169 tons, with 135 tons on drivers, 6,600 sq. ft. of heating surface and 88 sq. ft. of grate.

When larger dimensions than this are required, the Mallet articulated type is employed. Five examples are shown in Table I., two with six wheels coupled in each group, and three with eight. Of these, the four lighter engines represent current American practice for lines where heavy trains are to be taken over steep grades. The Virginian 2—8—8—2 is an exceptionally heavy engine. It is shown here rather as a maximum which is not likely to be passed for some time, than as an example of every-day American practice. It has nearly 27 tons on each of eight driving axles, 215 tons on the 16 coupled wheels, and as neither the weight per axle nor the number of coupled axles are likely to be increased for regular service, it seems improbable that anything very much heavier will be adopted in the near future.

TABLE III.

Passenger Locomotives.

Railway.	Class.	No. of Cylinders.	Single Exp. or Comp.	Saturated or Super.	Cylinder Diam. and St. Ins. Ins.	Driving Wheel Diam. Ins.	Boiler Pressure Lbs. per sq. in.	Total Weight. Lbs.	Weight on Drivers. Lbs.	Tractive Effort. Lbs.	Equiv. Heating Surface. Sq. ft.	Grate Area. Sq. ft.
Midland	4-4-0	2	S.E.	Super.	20½ × 26	84½	160	120,000	78,000	17,600	1,641	21·1
North British	4-4-0	2	S.E.	Super.	20 × 26	78	165	128,100	84,800	18,700	1,454	21·3
Prussian State	4-4-0	2	S.E.	Super.	21·7 × 24·8	82¾	170	131,000	73,500	20,500	2,122	24·8
Caledonian	4-4-0	2	S.E.	Super.	20¼ × 26	78	170	132,200	85,100	19,700	1,807	21·0
London and North Western	4-4-0	2	S.E.	Super.	20½ × 26	81	175	134,400	85,700	20,000	2,000	22·4
Great Eastern	4-6-0	2	S.E.	Super.	20 × 28	78	180	141,000	97,200	22,000	2,062	26·5
Prussian State	4-6-0	2	S.E.	Super.	22·6 × 24·8	69	170	150,600	104,500	26,700	2,426	28·0
London, Brighton, and South C'st	4-4-2	2	S.E.	Super.	21 × 26	79½	170	155,000	84,560	20,800	2,721	30·9
Great Northern (Eng.)	4-4-2	2	S.E.	Super.	20 × 24	80	150	155,500	80,600	15,300	2,695	31·0
French State	4-6-0	4	S.E.	Super.	16·9 × 25·2	80¼	170	157,500	107,600	25,900	2,158	29·9
Baden State	2-6-2	4	Comp.	Super.	$\left.\begin{matrix}14\cdot2\\23\cdot2\end{matrix}\right\}\times 25\cdot2$	67	228	158,700	102,700	22,600	2,492	40·4
Italian State	2-6-2	4	S.E.	Super.	14·2 × 23·2	73	170	160,400	102,400	18,600	2,896	37·7
Great Western	4-6-0	2	S.E.	Super.	18½ × 30	80½	225	161,300	122,800	24,300	2,271	27·1
Great Central	4-6-0	2	S.E.	Super.	21½ × 26	81	180	168,500	126,500	22,700	3,037	26·0
Prussian State	4-6-0	4	S.E.	Super.	16·9 × 24·8	78¾	170	171,000	112,000	26,400	2,465	28·1
North Eastern	4-4-2	3	S.E.	Super.	16½ × 26	82	160	172,500	89,260	17,580	2,774	27·0
Lancashire and Yorkshire	4-6-0	4	S.E.	Sat.	16 × 26	76	180	172,700	132,200	27,100	2,507	27·0
Prussian State	4-6-0	4	Comp,	Super.	$\left.\begin{matrix}15\cdot7\\24\end{matrix}\right\}\times 26$	78¼	213	175,000	112,300	22,000	2,610	31·6
Belgian State	4-6-0	4	S.E.	Super.	17·5 × 25·2	78	200	179,000	117,500	33,400	2,262	32·5
Nord	4-6-2	4	Comp.	Super.	$\left.\begin{matrix}16\cdot1\\23\cdot6\end{matrix}\right\}\times 26$	80¼	228	188,400	108,400	23,500	3,019	34·6
Bavarian State	4-6-2	4	Comp.	Super.	$\left.\begin{matrix}16\cdot7\\25\cdot6\end{matrix}\right\}\times\left\{\begin{matrix}24\cdot0\\26\cdot4\end{matrix}\right.$	73½	213	190,000	105,700	25,200	3,154	48·4
Italian State	4-6-2	4	S.E.	Super.	17·7 × 26·7	80	170	192,500	119,000	30,300	3,342	37·7
Baden State	4-6-2	4	Comp.	Super.	$\left.\begin{matrix}16\cdot7\\25\cdot6\end{matrix}\right\}\times\left\{\begin{matrix}24\cdot0\\26\cdot4\end{matrix}\right.$	71	228	194,000	105,400	27,800	3,054	48·4
Paris-Orleans	4-6-2	4	Comp.	Sat.	$\left.\begin{matrix}15\cdot3\\25\cdot2\end{matrix}\right\}\times 25\cdot6$	72¾	228	198,300	115,200	24,100	2,768	45·9
Paris-Orleans	4-6-2	4	Comp.	Sat.	$\left.\begin{matrix}16\cdot3\\25\cdot2\end{matrix}\right\}\times 25\cdot6$	76¾	228	199,000	116,700	23,000	2,768	45·9
French State	4-6-2	4	Comp.	Sat.	$\left.\begin{matrix}15\cdot0\\23\cdot6\end{matrix}\right\}\times 25\cdot2$	73	228	200,500	116,700	22,600	3,191	43·1
Paris-Orleans	4-6-2	4	Comp.	Super.	$\left.\begin{matrix}16\cdot5\\25\cdot2\end{matrix}\right\}\times 25\cdot6$	72¾	228	201,000	116,900	27,400	3,288	45·9
P.L.M.	4-6-2	4	Comp.	Super.	$\left.\begin{matrix}17\cdot3\\25\cdot6\end{matrix}\right\}\times 25\cdot6$	78¾	228	201,000	122,300	27,300	3,216	45·7
Paris-Orleans	4-6-2	4	Comp.	Super.	$\left.\begin{matrix}16\cdot5\\25\cdot2\end{matrix}\right\}\times 25\cdot6$	76¾	228	202,000	117,300	26,000	3,288	45·9
Southern Pacific	4-6-2	2	S.E.	Super.	22 × 28	77	200	221,000	141,500	30,000	3,528	49·5
Belgian State	4-6-2	4	S.E.	Super.	19·7 × 26	78	200	227,000	125,600	30,900	3,068	53·8
Southern	4-6-2	2	S.E.	Super.	24 × 28	72½	185	233,000	142,300	34,900	4,048	54·0
Wabash	4-6-2	2	S.E.	Sat.	24 × 26	74	200	246,000	158,500	34,400	4,473	63·0
Norfolk and Western	4-6-2	2	S.E.	Super.	22½ × 28	70	200	249,000	163,900	34,500	4,493	44·7
Nashville and Chatanooga	4-6-2	2	S.E.	Sat.	23 × 28	72	200	254,000	157,300	35,000	4,983	66·7
Baltimore and Ohio	4-6-2	2	S.E.	Sat.	24 × 32	74	205	263,800	166,200	43,500	5,017	70·0
Atchison	4-6-2	4	Comp.	Super.	$\left.\begin{matrix}17\tfrac{1}{2}\\29\end{matrix}\right\}\times 28$	73	210	268,800	163,500	30,000	4,372	57·6
New York Central	4-6-2	2	S.E.	Super	23½ × 26	79	200	269,400	171,300	30,900	4,631	56·5

more solid road bed enables the American engines to get an adhesive weight of up to 108 tons with only four-coupled axles, while the heaviest European engines with five-coupled axles have only about 87 tons on drivers. In America at the present time, the most usual type of goods or freight engine, except where the heavy Mallets are required, is the Mikado, or 2—8—2. This type with four-coupled wheels and two-wheeled trucks front and back gives a most satisfactory engine. Sufficient boiler capacity is obtained to give fairly high speeds, while the rear truck permits ample firebox capacity and grate area. The engines shown in Table I. have from 4,500 sq. ft. to 5,500 sq. ft. of heating surface and up to 70 sq. ft. of grate. A more powerful engine is obtainable by using the 2—10—2 type, and a certain number have been built. The Burlington engine referred to in Table I., which, when built, the heaviest non-articulated engine, weighs

It will be noticed that the majority of the engines referred to employ superheated steam, and about half of the whole number have two cylinders expanding the steam once only. The French, Bavarian, Baden, and Italian engines use four compound cylinders, while the extra heavy American engines are Mallet compounds.

There is a fairly regular progression in the heating surface with the increase in the total weight. Each square foot of heating surface requires from 60lbs. to 70lbs. of total weight, and as each horse-power requires about 2¼ sq. ft. of heating surface, the engines weigh from 135lbs. to 160lbs. per horse-power, or from 14 h.p. to 16·5 h.p. can be obtained per ton of total weight.

The correctness of the assumption made above that $2\frac{1}{4}$ sq. ft. of heating surface will produce 1 h.p. depends on the grate being properly proportioned to the heating surface, due regard being paid to the quality of the fuel to be burnt. The influence of the quality of the coal is visible in Table II. The English engines are able to use a good quality of coal, and have grate areas of about 23 sq. ft., the largest in the table being the Great Central 2—8—0 with 26·0 sq. ft. The German engines of the same size have about 32 sq. ft., that is, 12·5 per cent. more, and are hence adapted to a lower grade of fuel. The larger French engines have from 35 sq. ft. to 40 sq. ft. of grate, which stands to their weight in about the same proportion as is found in the British engines. The Belgian 2—10—0 has 54·9 sq. ft. of grate, which is sufficient to burn comparatively inferior coal.

The American engines have proportionately more grate than the English or French. The 2—8—2 type engines have from 60 sq. ft. to 70 sq. ft. of grate, while the Burlington 2—10—2 has 88 sq. ft., and the Virginian Mallet 99 sq. ft. As each 20 sq. ft. of grate will burn about one ton of coal per hour, it follows that the Mikado, or 2—8—2 type, are capable of consuming from 3 to 3·5 tons of coal per hour, and the larger engines from 4 to 5 tons. It is practically impossible for a man to fire coal at this rate, and therefore, if these large engines are to develop their full power continuously, they must either burn oil fuel or be fitted with some kind of mechanical stoker.

Passenger Engines.—On examining the engine shown in Table III., it appears that the number of types employed is fewer, and the range of weight is less. The heaviest engine in the table is an American "Pacific" type weighing about 269,000lbs. (120 tons). There is not in passenger service the same tendency as in goods service to increase the weight of the locomotives. Concentration of loading and reduction in the number of trains does not produce the same economies in passenger as in goods service. Among the passenger, as among the goods engines, the lightest are the English, and the heaviest the Americans, but the divisions are not so sharply drawn as in the goods engines, and some continental passenger locomotives are lighter than the heaviest English engines, and other continental engines are heavier than the lightest Americans. In England and Germany the 4—4—0 and 4—4—2 types are still in active service, but it appears that four-coupled engines are obsolescent elsewhere and the bulk of modern main line passenger service is being performed by six-coupled engines. In England and in Prussia, the 4—6—0 suffices, but elsewhere in Europe and in America the 4—6—2, or Pacific type, is required to provide sufficient boiler capacity.

As in the goods engines, superheated steam is predominant, and about half the number of engines referred to have two single-expansion cylinders. One engine has three and six have four single-expansion cylinders, the remainder being four-cylinder compounds. The single-expansion engines include all of the English, and all but one of the American engines, while a large majority of the continental engines are four-cylinder compounds. While there are greater advantages in compounding with passenger than with goods engines, it appears that the decision as to whether the advantages or disadvantages of compounding are greater is largely a matter of nationality, the English and American giving the upper hand to the disadvantages and the continental designers to the advantages. It may be of interest to set out briefly the advantages and disadvantages of compounding when four cylinders are employed.

The advantages are: (1) A saving of from 15 to 20 per cent. in coal and water, whether saturated or superheated steam be used; (2) a more even tractive force; (3) a reduction in the pressure on the connecting rod crank pins; (4) a very much better balance of the machinery, tending to reduce the wear on the bearings and to make the locomotive much less destructive to track and bridges.

Against these are to be set as disadvantages: (1) Four cylinders instead of two, with a consequent increase of weight and first cost; (2) a greater number of moving parts to be oiled, inspected, and maintained.

The choice for or against compounding will be determined by local conditions in which the class of men available for the care and operation of the locomotives will be of importance. Where simplicity is of prime importance, single expansion will be used, but where a slight complication can be permitted for the sake of economy, compounding is indicated. It is hard to see why four single-expansion cylinders should be used. Four cylinders are desirable in heavy high-speed engines for the sake of balancing, but if four cylinders are used, compounding introduces practically no further complication and secures considerable economy.

With regard to heating surface and grate area there is little to be added to what was said in considering the goods engines. The American and the continental engines take full advantage of the rear truck to secure ample heating surface and grate area, and the largest American Pacific type engines have up to 5,000 sq. ft. of heating surface and 70 sq. ft. of grate.

Having now considered the locomotives broadly, a hasty examination of them will be made, grouping them so as to get some idea of the general practice of the various roads and countries.

TABLE IV.

Number of Locomotives of the different Types by Nationalities.

Type.	British.	French.	German.	Italian.	Belgian.	American.	Total No.
			Passenger Engines.				
4—4—0	4	—	1	—	—	—	5
4—4—2	3	—	—	—	—	—	3
2—6—2	—	—	1	1	—	—	2
4—6—0	4	1	3	—	—	—	8
4—6—2	—	7	2	1	1	8	19
Total	11	8	7	2	1	8	37
			Goods Engines.				
0—6—0	3	—	—	—	—	—	3
2—6—0	3	—	—	—	—	—	3
4—6—0	1	1	—	—	—	—	2
0—8—0	3	—	1	—	—	—	4
2—8—0	1	3	1	—	—	—	5
2—8—2	—	—	—	—	—	8	8
0—10—0	—	—	2	1	—	—	3
2—10—0	—	3	—	—	1	—	4
2—10—2	—	—	—	—	—	1	1
Mallet ..	—	—	—	—	—	5	5
Total ..	11	7	4	1	1	14	38

Great Britain. — Most of the roads are represented by two locomotives only, one goods and one passenger, and consequently the complete practice of any one road is not represented. The types presented, however, by the different roads are sufficiently varied to give a reasonably comprehensive picture of British practice. As has been pointed out, the lighter types, such as the 0—6—0 and the 0—8—0 in goods service and 4—4—0 and 4—4—2 in passenger service are still used in England, while elsewhere growth in the weights of trains has pushed these types into the background. The 4—6—0 type is being largely used for passenger service, and as the demands on the motive power department continue to increase, this type must become more and more important. For fast goods service a new type for England, the 2—6—0, or Mogul, is being introduced by the Caledonian, by the London, Brighton, and South Coast, and by the Great Northern. Many of the runs in England are short enough to be handled by tank engines, and some excellent results are being obtained with this class of machine.

In examining the quality of steam used, it will be seen that all but three of the British engines shown in Tables II. and III. are equipped with superheaters, and while this does not mean that saturated steam is a thing of the past in Great Britain, it does indicate that an increasingly large number of new engines will be fitted with superheaters. Both of the Lancashire and Yorkshire engines use saturated steam, but while Mr. Hughes gives these as typical of his modern practice, he has informed the author that he is giving superheating his close attention, and expects to increase his use of the hot steam. All of the engines in the two tables are single

expansion, and it appears that compounding is hardly doing more than holding its own.

France.—The goods service is being handled mainly by 2—8—0 and 2—10—0, and the passenger service by 4—6—2 engines. France has, of course, always been the country of 4-cylinder compound engines, and this style of machine is being maintained in spite of the introduction of superheating. With the first introduction of superheat, there was a tendency to revert to single expansion, but the evidence is now clear that compounding is just as advantageous with superheated as with saturated steam.

Mr. Maréchal, of the Paris, Lyons, and Mediterranean Railway, has given the author a most interesting account of the development of the motive power of that railway since 1905. The engines designed at that time were 4—6—0 for passenger and 4—8—0 for goods service, the 4—6—0 replacing the 4—4—2 engines, so as to have ample adhesion for the heavier trains. It soon became evident that more power was required in passenger service, and Pacific type 4—6—2 engines were introduced. In the goods service the 4—8—0 are being succeeded by 2—8—0 engines, the front coupled axle and the front carrying axle being equalised together to form a Zara truck. This type has proved satisfactory, as it gives an engine with as much power as the 4—8—0, with a slightly smaller total weight and a slightly greater adhesive weight.

The French State, in addition to the 4—6—2 type, has some 4-cylinder single-expansion superheater 4—6—0 engines, of which 20 were put into service in 1912. These engines handle trains of 365 tons on grades up to 1 per cent., and with a train of 245 tons can sustain speeds of 68 miles per hour on the level, 60 miles per hour on a one-half of 1 per cent. grade, and 46 to 48 miles per hour on a 0·9 per cent. grade.

The Paris-Orleans are using Pacific type superheater engines for their best trains, and in tests made in service between Paris and St. Pierre-des-Corps, 143 miles, the following results were obtained:—

Train behind Tender	Average running speed	Horse-power at rail	Consumption per horse-power hour at rail	
Tons.	Miles per hour	h.p.	Water lbs.	Coal lbs.
506·5	48·4	1,182	18·3	2·38
557·5	49·5	1,377	18·5	2·35
401·5	56·1	1,426	18·8	2·52
426·5	56·6	1,480	18·9	2·74
366·5	58·0	1,487	18·6	2·72

The line on which these tests were made has one grade of 0·8 per cent. about six miles long, but is otherwise not a difficult profile. The fuel used was briquettes of good quality, having a heating value of about 15,150 B.Th.U., and only 5·6 per cent of ash. The economy effected by the powerful modern engines is strikingly shown by some figures given by the Paris-Orleans Railway for the coal consumed in hauling the Paris-Bordeaux express from Paris to Tours. In 1897 the train weighed 175 tons, and 3,235 kgs. of coal were burnt. In 1911 the train on the same timing weighed 340 tons, an increase of 94 per cent., while the coal burnt was 3,583, an increase of only 11 per cent. The coal consumed per ton of train, which was 18·5 kgs. in 1897, was only 10·5 in 1911.

Germany.—The German Empire is represented in this paper by three railways, the Baden and the Bavarian State Railways, of South Germany, and the Prussian State Railway, of North Germany. The South German engines are all four-cylinder compound superheaters. Baden uses 2—8—0 for goods, and 2—6—2 and 4—6—2 for passenger, while the Bavarian engines are 0—10—0 for goods and 4—6—2 for passenger. The South German roads stand alone in Europe in using bar frames of American pattern.

The goods engines shown for the Prussian State are 0—8—0 and 0—10—0, both being two-cylinder single-expansion superheater machines. The larger of them takes train of 1,000 tons on a grade of 0·9 per cent., at a speed of about 11 miles per hour.

The passenger engines are a 4—4—0 and three 4—6—0's. The 4—4—0, which is for light high-speed passenger service, and the lightest 4—6—0, which is for moderate-speed work, are two-cylinder single-expansion superheaters. For heavy high-speed trains two types of 4—6—0 superheater engines are used. The first of these types to be introduced expanded the steam once only, but recently the design has been modified to use compound cylinders, and the results obtained have been so satisfactory that it is probable that the Prussian State will return permanently to compound cylinders for the heaviest high-speed engines. The 4—6—0 compound has shown itself capable of taking a train of 590 tons on a level line at 59 miles an hour, and a train of 470 tons up a continuous grade of 1 per cent. at 35 miles an hour. When working trains of 514 tons weight, the water consumption is given as 18lbs. per horse-power hour, while the single expansion engines of the same class require 23·8lbs.

Belgium.—The 2—10—0 goods and the 4—6—2 passenger engines are the heaviest European locomotives shown in the paper. For lighter passenger service a 4—6—0 type is used. All of these engines have four single-expansion cylinders and use superheated steam.

Italy.—The heaviest goods traffic is handled by 0—10—0 type engines with four compound cylinders and saturated steam. As much of the passenger service is not handled at very high speeds, engines of the 2—6—2 type, having the Zara type of truck, give satisfactory results. A 4—6—2 type has been introduced, but for the present at least this engine is more powerful than is absolutely necessary, and it is so heavy that it cannot be used on all parts of the railway. Both the passenger engines shown use superheated steam and four cylinders, the 2—6—2 being compounded and the 4—6—2 single expansion.

United States.—As has been pointed out, the 2—8—2 and the Mallet are the modern American goods engines. The passenger service is handled by 4—6—2 engines. Except in the case of the Mallet engines, compounding is little used. The tables show only one example, that of the Atchison 4—6—2, which is four-cylinder Vauclain compound. Two cylinders are almost universally used, and superheating is not quite so widely used as in Europe.

Conclusions.—As a result of the foregoing rather cursory examination of the various engines, a few general conclusions can be drawn as to the tendencies noticeable.

The use of superheated steam is being widely extended.

Compounding shows a revival on roads where it has been dispossessed by the introduction of superheating, and while there is plenty of evidence that valuable economies in coal can be effected by the double expansion of the steam, yet the engineer who decides to forego them for the sake of simplicity will do so in very good company.

In the matter of wheel arrangement there is little room for choice. In goods service the number of coupled axles is definitely determined by the weight of train to be hauled and the weight allowed on each driving axle. In passenger service everyone is being forced to the use of six-coupled wheels, and except in England and Germany it is being found desirable to use a two-wheeled rear truck, thus producing a Pacific type machine to obtain sufficient boiler power.

The fact stated seven years ago by Monsieur Desmoulins becomes continually more obvious. The more difficult the problem presented to the locomotive engineer the fewer are the solutions which will prove satisfactory.

Third International Congress of Refrigeration.—The third International Congress of Refrigeration will be held in the United States in September, 1913. The formal opening will take place at Washington on September 15th, when a reception will be held by the President of the United States. On the 17th the other meetings, business and scientific, will begin at Chicago, and continue daily until the 23rd. It is proposed to have half-day sessions for the reading of papers, &c., during this time, and that the rest of the day should be spent in visits to points of interest, such as the Union Stock Yards, Military Post, Naval School, works of the Illinois Steel Company, cold-storage warehouses, ice-plants, &c. The Secretary-General of the Congress is J. F. Nickerson, Esq., 431, South Dearborn Street, Chicago.

THE TESTING OF FANS.

At a meeting of the Mining Institute of Scotland, held on April 12th, a paper, entitled "The Testing of Fans: A plea for standardised test conditions," was read by Mr. John Watson, M.I.Mech.E. He observed that fan tests that were presumably conducted and published in good faith varied so widely in their results, particularly in regard to efficiency values, that it would be well if the test conditions were standardised. The objects of fan testing were, generally, to determine (*a*) the quantity of air per minute passed by the fan, (*b*) the resistance overcome by the fan, namely, the water-gauge, (*c*) the efficiency of the fan, and, in some cases, (*d*) the efficiency of the whole plant.

The quantity of air passed by a fan was, he remarked, not infrequently calculated from a single anemometer measurement made in the fan chimney or in the fan drift. The more ordinarily accepted method was to divide the area of the chimney or drift into a number of rectangular and approximately equal areas, in each of which a reading was taken by the anemometer. From these readings, after the correction (if any) for the anemometer used had been applied, the average velocity per minute over the whole area was determined. The variation of velocity was not regular, and the velocity in any one of the test areas could hardly be considered uniform over the whole space, or even uniformly variable. This raised the point whether the average velocity as usually determined was correct for areas over which the velocity varied widely. In the author's opinion, the most accurate results were obtained when the anemometer was kept continually moving at a uniform rate over the small area being measured, and then moved on to the next area without any stoppage, and so on; the instrument being kept continually on the move for the period during which it was being used in each area. It was assumed that the time for which the anemometer was kept in any space was 1 minute; but smaller periods would serve if it was necessary to shorten the time occupied in obtaining a complete reading over a fairly large area.

It was, he said, important that the anemometer should be calibrated both before and after tests, and that a type of instrument suitable to the velocity being measured should be used. This was especially so in the case of measurements made in the fan chimney, where the velocity was usually high. In whatever way the average velocity per minute of the air had been determined, the product of that velocity and the area in which it was obtained gave the quantity of air passed per minute through the fan. This might be more or less than the fan performance, as the natural ventilation of the mine would in some cases assist the fan, and in other cases be against it. The true performance of the fan could therefore only be arrived at after allowance had been made for the effect (if any) of natural ventilation. If anemometer measurements were taken in a fan drift, they should be made in a part of the drift sufficiently far from the ear of the fan to be beyond the region of whirling air, and in a straight or nearly straight part of the drift, so as to ensure a moderately even distribution of the air over the whole area. On account of the great variation in the length and form of fan drifts, the author was of opinion that it was preferable to measure the quantity of air in the fan chimney; and the results of measurements made simultaneously in a fan chimney and in a fan drift favourable for accurate measurement showed that the quantity of air obtained either way was in very close agreement.

Several styles of water-gauge tube-termination in the fan drift were illustrated. It was rather difficult to make exact measurements of the water-gauge, on account of the oscillation of the water column, and it was therefore advisable to adopt means to eliminate this oscillation. Even if this had been done, two observers often gave different measurements of water-gauge, and the effect of a small error in measuring the gauge was important, especially at low water-gauges.

When the power in the air had been found, the efficiency of the fan was ascertained by dividing the power in the air by the power exerted on the fan shaft. The power exerted on the fan shaft must, in the case of direct engine-driven fans, be measured by a dynamometer, or calculated from the indicated horse-power of the engine multiplied by a factor, namely, the efficiency of the engine; or, in the case of direct motor-driven fans, by the efficiency of the motor. In the case of fans driven by belt or ropes, an additional factor was employed, so as to allow for loss of power in the drive. When the drive was by motor, the electrical input should be measured by a wattmeter.

The efficiency of the whole plant was ascertained by dividing the work done on the air per minute by the work of the engine or motor per minute. The degree of exhaustion produced in the interior of the fan could be measured on the water-gauge by completely stopping the entrance of air to the fan drift, and running the fan at its speeds as was done for testing purposes. The degree of exhaustion due to the velocity of the fan blades could be calculated and reduced to a water-gauge usually called the "theoretical water-gauge." The manometric efficiency of the fan was found by dividing the gauge produced in the fan drift, when all entrance of air had been stopped, by the calculated theoretical water-gauge. The author had not, however, been able to determine what useful object was served by obtaining this ratio.

It was important to make a careful test of the difference between the water-gauge obtained in the closed drift and the water-gauge obtained in the open drift for the same speed of the fan. This difference was the measure of the resistance to the passage of the air through the fan, and was well worth knowing.

In evidence of the divergence of practice in regard to measurement of the air and the water-gauge, the following stipulations were extracted from recent fan specifications, not with the view of criticising the stipulations themselves, but solely for the purpose of exhibiting the differences of opinion existing:—(1) The quantity of air and the water-gauge were to be measured in the upcast shaft. (2) The quantity of air and the water-gauge were to be measured at the pit-bottom near the separation doors. (3) The quantity of air was to be measured in the fan drift at a place specified, and the water-gauge was to be measured by a tube led into a box in the side of the fan drift covered by a perforated plate. (4) The quantity of air, the speeds, the horse-power in the air, and the brake-horse-power at the fan pulley, with varying water-gauges of 3, 4, 5, and 6in. at constant equivalent orifice, must be stated.

When conditions differing so much were laid down, and where such differences in actual practice in testing as had been referred to were possible, one need hardly wonder that the results of tests were not readily comparable. The author was of opinion that the whole subject of fan testing required careful consideration, in order that conditions universally applicable might be devised, so that the results of tests which might be carried out under these conditions should be readily comparable. He suggested the appointment of a committee to confer with the other Federated Institutes on this important subject.

Powerful Electric Locomotives.—The New York Central and Hudson River Railroad Company has recently placed an order with the General Electric Company, Schenectady, N.Y., for nine of what will be the most powerful electric locomotives ever built. They will weigh 100 tons and will exert a sufficient tractive effort to haul a train weighing 1,000 tons at a speed of 60 miles per hour. In regular service they will have a capacity for developing 1,400 h.p. continuously and for short periods 5,000 h.p. can be delivered. The new locomotives will have an articulated frame with bogie guiding trucks at each end. The cab containing the engineer's compartments and that for the operating mechanism will be swung between the two parts of the frame on the centre pins. Each section will be equipped with two two-axle trucks having a bi-polar gearless motor mounted on each axle. Each motor will have a capacity of 325 amperes at 600 volts for one hour or a continuous rating of 260 amperes under forced ventilation. They will be connected permanently in parallel in pairs, and the pairs can be connected in series, series-parallel, or parallel combinations. The current will be collected by eight under-running third-rail shoes, or by two overhead trolleys, when operating on gaps on the third-rail.

ELECTRO-BESSEMER FURNACE.

A NOVEL type of electric refining furnace, which is a combination of the electric and Bessemer processes, is shown in the accompanying views, for which we are indebted to "The Iron Trade Review." The furnace is being introduced by L. P. Hoult, Muskegon, Mich., and is known as the electro-Bessemer type. It consists of a closed converter with an opening in one side, through which the charge may be introduced and slags added and withdrawn. It is mounted on bearings of ample size, and is capable of being tilted within an angle of more than 180°, the motive power being either electric or hydraulic,

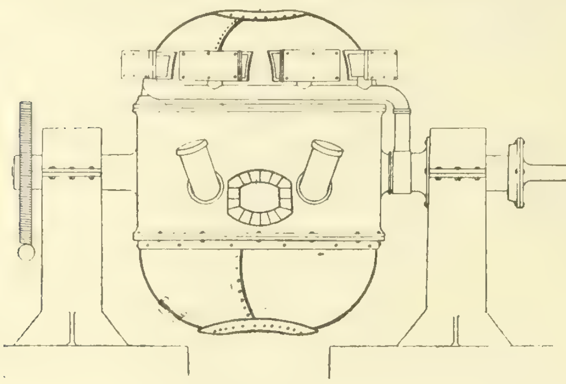

FIG. 1.—ELECTRO-BESSEMER FURNACE: FRONT ELEVATION.

with suitable gearing interposed. One end of the furnace is fitted with blast tuyeres for blowing. At the other end of the vessel electrodes are arranged entering through the furnace wall. A tapping hole is provided at this end of the furnace, which may be used for the removal of the finished product, if desired. Samplings may be taken from the charging opening, which might also be used for pouring the molten metal. The electrodes are fitted with cooling jackets of cold air or water. When operating, the furnace is preheated in the ordinary way, and it is then charged with molten metal from a cupola or blastfurnace mixer, the furnace being tilted into a horizontal position. It is then brought to a vertical position, the Bessemer portion containing the charge. The blast comes into action automatically as this position is gained and the

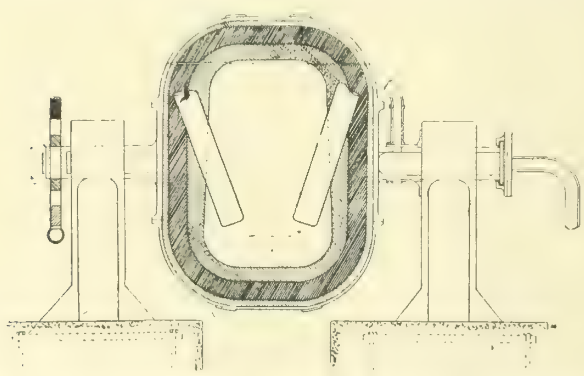

FIG. 2.—ELECTRO-BESSEMER FURNACE: CROSS SECTION SHOWING POSITION OF ELECTRODES.

process of conversion proceeds as in the ordinary converter. Meantime the electric portion of the furnace is heated by the hot gases, &c., resulting from the Bessemer blow. On the completion of this part of the process the furnace is tilted, and the metal is transferred to that end which is provided with electrodes. Current is switched on, and the refining operation is continued to any desired extent. Both arc and resistance heating can be obtained in the furnace. The average specific energy consumption is 100 kw. hours per ton of steel produced. If a larger unit, namely, 7 or 8 tons, is installed with continuous operating, the consumption is well below 90 kw. hours per ton of steel.

New Allan Liner.—The Allan Line Steamship Company's quadruple turbine steamer "Calgarian" was launched on Saturday last from the Clyde yard of the Fairfield Shipbuilding Company. The "Calgarian," which is intended for the Liverpool-Canadian service, is 600ft. in length and is of 18,000 gross tons.

INDUSTRIAL AND TRADE NOTES.

Miners' Wages Advanced.—A meeting of the English Coal Conciliation Board was held in London on the 15th inst. to consider the men's application for a 5 per cent. advance in wages. The return of the selling prices of coal from representative collieries in the area showed an average price of 9s. 3d. per ton, as compared with 8s. 7d. when the last advance was granted. The Board granted the application. The advance represents an addition of about £20,000 per week, or £1,000,000 per annum.

Electric Power Output of the United States.—The combined electric output of the 7,500 central stations in the United States for the year ended December 31st, 1912, was 12,000,000 h.p. These figures include only public service companies, and take no account of the great railroad and manufacturing companies which produce and use their own power, so that the total power generated is easily double the output of the central stations. It is estimated that the total business in electrical machinery in the United States in 1912 amounted to approximately 60 millions sterling.

Trials of a Large Oil Tank Steamer.—The largest oil tank steamer in the world, the "San Fraterno," built by Messrs. Swan, Hunter, and Wigham Richardson, Wallsend-on-Tyne, underwent her trials in the Tyne on the 17th inst., and these proved in every way satisfactory. The vessel has a deadweight capacity of 15,500 tons. The speed stipulated for was 11½ knots, and during the trials 12 knots were averaged. Owned by the Eagle Oil Transport Company, Ltd., she is the first of 10 similar vessels, and the company also owns nine vessels of 9,000 tons capacity each. The vessel will shortly proceed to Mexico on her maiden voyage.

Exchange Telephones.—In the House of Commons recently, the Postmaster-General stated that the total number of exchange telephones in London on December 31st, 1912, was 227,313, a net increase of 15,972 telephones during the year, or 7·56 per cent. net increase on the telephones at the beginning of the year. Since December 31st, 1908, when the percentage was 12·93 per cent., there had been an annual decline. The total number of exchange telephones in the provinces on December 31st, 1912, was 452,839, the net increase of exchange telephones during the year being 22,847, the largest in any year during the period under review.

World's Largest Dredger.—Messrs. Lobnitz & Co., Ltd., Renfrew, launched on Saturday last, for the Suez Canal Company, the dredger "Penelope," which is the largest bucket dredger afloat. The vessel is 309ft. in length on deck, 47ft. in breadth, and 20ft. 2in. in depth. The dredging machinery is of the most improved type, having independent dredging engine direct geared to the top tumbler. The twin-screw propelling machinery is independent, and all the gearing has machine-cut teeth. The bucket ladder is fitted with Lobnitz's patent elastic suspension to facilitate dredging hard ground in a seaway, the vessel being intended to work at the entrance to the Suez Canal.

Machine Tool Trade in America.—A special Consular Report has recently been issued by the United States Department of Commerce and Labour, dealing with the markets for machine tools in Latin America. The countries included are for the most part agricultural, and the demand for machine tools has been small, but there seem to be some markets that are steadily expanding. The report contains lists of the importers and users of machine tools, descriptions of the sales methods employed, and opinions on the possibilities of the different markets, &c. The report may be seen by machine tool manufacturers in the United Kingdom at the Commercial Intelligence Branch of the Board of Trade, 73, Basinghall Street, London, E.C.

A Large Surfacing Condensing Plant.—The Mirrlees Watson Company, Ltd., Glasgow, have recently secured a repeat order for a large surface condensing plant for the Leeds Corporation Electricity Works, capable of dealing with 130,000lbs. steam per hour. The plant will be connected to a turbo-alternator, for which Messrs. Willans & Robinson have just received the order. The condenser of this installation is of a very special design to suit the conditions of dirty water obtained for condensing purposes from the river Aire. This water contains a large amount of woollen material, which, along with mud, soon clogs up the ordinary type of condenser. The condenser is designed so that all the tubes can be cleaned out whilst the plant is in operation. The flow of the cooling water can be reversed without interfering with the running of the plant. The condenser is of the vertical type design, having 24,800 sq. ft. cooling surface. The total height of the condenser is 28ft. and weighs 85 tons.

The Invention of the Sewing Machine.—It appears that the credit for the invention of the sewing machine, which is generally given to America, is not well founded. According to our contemporary, "Commercial Intelligence," Mr. J. J. Darby, principal examiner in the United States Patent Office, states that the earliest attempt

at sewing by machinery of which there is any authentic record was in 1755, in which year a machine was patented in England by Charles F. Weisenthal. In 1790 another English patent was granted to one Thomas Saint, and in 1804 another Englishman, named Duncan, made a chain stitch machine. A Frenchman named Barthelemy Thimonnier invented, in 1830, a machine that embodied the Saint principles, with one exception. The first American patent was issued to a man named Lye in 1836. What was probably the first lock stitch machine was built in 1832-34 by Walter Hunt, of New York City. Many patents followed, but the great epoch of the sewing machine was from 1846, when Elias Howe patented his machine, to 1851, when the Wilson patent was issued.

Prospects of United States Petroleum Industry in 1913.—H.M. Embassy at Washington, in a recent report, states that during the months of January and February the feature of chief interest was the continued rise in the price of crude petroleum. This rise took place in all parts of the country, with the exception of California, where it has so far remained stationary, although the consumption in the latter State has increased to such an extent as practically to overtake the production. During the first months of this year the production has increased in Oklahoma owing to the development of the Cushing oilfield, and in the northern part of Texas owing to increased activity at Electra. Operations in other parts of the United States have only been sufficient to continue production at approximately the same as last year. The increased price of oil has stimulated drilling, and very great efforts will be made this spring to increase the production of the older fields. The Director of the Geological Survey considers that, generally speaking, the output of petroleum in the United States for this year will not differ materially from that of last year.

The Warwickshire Coalfield.—Some interesting history relating to this coalfield was given in an address recently delivered by Mr. J. W. McTrusty, mining lecturer under the Warwickshire County Council. Warwickshire coalpits had been troubled with spontaneous combustion from the very earliest times. They had records of fires in 1603, and in 1604 it was recorded that collieries were affected by damp. Those dates were not the beginning of mining in Warwickshire. The first definite record of mining in the county was in 1275, in the Chilvers Coton district. In 1338 shafts were being sunk near Nuneaton. In 1603 records again referred to mining in the Nuneaton district, and it was interesting to note that the names which applied to the seams at the present time applied in those days—ryder coal, slate coal, and seven foot coal. The mining industry developed very slowly for a time. From the historical point of view it was interesting to note that the second steam-engine that was made was fixed at Nuneaton in 1715. In 1776 Warwickshire was considered to have the most powerful pumping engine in this country, and it was fixed at Hawksbury Lane colliery. In 1725 there were about 50 collieries in Warwickshire, a group of seven being in the Wilnecote district.

Employment in the Engineering Trades.—The Board of Trade report on the state of the labour market states that employment continued good generally in March. There was an improvement in the iron and steel trades, while in coal mining, engineering, and shipbuilding the high level of recent months was maintained. There was, however, a marked decline in the tinplate trade. It is reported by Labour Exchanges that there was a continuance of the large demand for workmen of all classes in the shipbuilding trades, and in the engineering trade there was still a scarcity of labour in some districts. The upward movement in wages continued. Trade unions with a net membership of 908,276 reported 17,533 (or 1·9 per cent.) of their members as unemployed at the end of March, 1913, compared with 2·0 per cent. at the end of February, 1913. The changes in rates of wages taking effect in March resulted in an increase of nearly £24,000 per week in the wages of 224,000 workpeople. The number of trade disputes beginning in March was 81, and the number of workpeople involved in all disputes in progress during the month was 41,983, as compared with 45,382 in February, 1913, and 1,040,542 in March, 1912, when 1,000,000 workpeople were involved in the national coal strike.

Inspector's Strictures on Municipal Trading.—In the course of a Local Government Board enquiry, at Coventry, into the application of the Corporation to borrow a further £20,000 for the electricity undertaking, the Inspector (Mr. H. B. Hooper, M.Inst.C.E.) expressed a strong view as to the application of profits made by the trading of the department while there was a mass of outstanding capital. He said the Corporation last year made £16,000 profit on electricity, and applied £4,000 in relief of rates instead of paying back again some of its outstanding capital, which had doubled in the last six years. He did not question that Coventry had done very well, but the city was applying money in relief of rates, and was still going on borrowing in order to do so. The result was that the ratepayer had to pay more in the long run. Again, 2000 electricity consumers were making profits for 115,000 people, one fiftieth of the population making a contribution to the rates for the benefit of others who did not use electrical energy. He hoped the Council would seriously consider the question, and, without relieving the rates, look to the future and avoid further borrowing of money. The department was in business, and there was no sentiment about it at all. Coventry was a very enterprising city, and could not afford to be generous, and should supply cheap power.

Suspension of Electric Iron Smelting and Copper Refining in Norway.—H.M. Consul at Christiania reports that, according to the local press, the "Aktieselskabet Hardanger Elektriske Jern og Staal verk," a company formed for the electric smelting of iron near Odda, has resolved to discontinue the undertaking on account of the cost of production, and to let the works to a French syndicate which proposes to manufacture some kind of fertiliser. The works of this company were the first electric iron ore smelting works in Norway, and their closing will probably prove a serious blow to the further development of the industry in that country; indeed, one company whose electric smelting works are not yet completed is said to be holding its scheme in abeyance for the time being. The "Aktieselskabet Bandak Electrolytiske Kobberverk"—formed to refine copper ore at the Aamdal mines by the Hybinette process—has decided to close its works from April 30th, owing to an insufficiency of ore in the mine, though the actual refining process is said to have been successful. The local press states that the company intends to re-erect the copper extracting works on the coast near the Christiania Fjord. The company owns the Hybinette process for the extraction of copper and zinc from the purple ore from cellulose factories, as well as from natural ores, and it is said this move to the coast points to the intended realisation of the project for smelting the refuse from Norwegian cellulose factories.

Russian Industries in 1912.—According to the Journal of the Russo-British Chamber of Commerce, 1912, like the two preceding years, witnessed a general improvement in the economic position of Russia. The improvement, however, was by no means evenly distributed over the various branches of trade. Good demands, high prices, a larger influx of capital, and the opening of new enterprises and the enlargement of old ones, represent in general terms the industrial development in 1912. Mining and the allied industries shared very largely in this development. The metallurgical industries, working at high pressure, were unable to keep pace with the large number of orders received. In spite of a maximum home production and large imports from abroad there was a shortage of pig iron, while the demand for steel and metal manufactures was very firm all through the year, chiefly on account of an unusually large consumption for railway and municipal requirements. The output of the iron works attained record figures, while there was a considerable increase in the production of copper. The coal and oil industries experienced similar conditions. The demand for fuel was in excess of the supply, so that towards the end of the year, notwithstanding a marked increase in the import of coal from abroad, a shortage was felt, while prices of coal and petroleum rose perceptibly. A tendency towards a more general employment of electrical energy was noticeable, which resulted in an increased home manufacture and imports of motors and dynamos.

METAL QUOTATIONS.

TUESDAY, APRIL 22ND.

Aluminium ingot	95/- per cwt.
" wire, according to sizes, &c. ......from	112/- "
" sheets " " ...... "	120/- "
Antimony ......£31/-/- to	£33/-/- per ton.
Brass, rolled	8¼d. per lb.
" tubes (brazed)	10⅜d. "
" " (solid drawn)	9d. "
" " wire	8⅜d. "
Copper, Standard	£67/17/6 per ton.
Iron, Cleveland	69/1½ "
" Scotch	75/1½ "
Lead, English	£18/10/- "
" Foreign (soft)	£17/15/- "
Mica (in original cases), small	6d. to 3/- per lb.
" " " medium	3/6 to 6/- "
" " " large	7/6 to 11/- "
Quicksilver	£7/10/- per bottle.
Silver	$27\frac{11}{16}$d. per oz.
Spelter	£25/10/- per ton.
Tin, block	£227/10/- "
Tin plates	14/- "
Zinc sheets (Silesian)	£28/10/- "
" (Stettin; Vieille Montagne)	£28/12/6 "

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Engine starting device. Kettering. 29085.
Engine starting devices. Kettering. 29344.

1912.

Methods of producing wrought shapes of manganese steel. Potter. 2324.
Clutches. Humphries. 2385.
Working of gas producers. Testrup & Rigby. 5024.
Machines for operating upon propeller blades. Ito. 5287.
Portable scaling hammers. Stewart & White. 5663.
Process for coating iron sheets and plates with aluminium. Woud. 6971.
Cam-regulating mechanism. British Thomson-Houston Company. 7096.
Starting internal-combustion engines. Willis. 7118.
Driving gear for motor-vehicles. Hartley. 7473.
Steam boiler tube scrapers. Restucci. 7484.
Internal-combustion engines with sleeve distribution. Van Lammeren. 7554.
Method of and apparatus for controlling the speed of a moving body and its application to lifts, hoists, or other elevators. Gazagnaire. 7771.
Furnace fire bridges. Wager. 7791.
Apparatus for operating the points of railways and tramways. Thomson. 7938.
Radiators for internal combustion engines. Haegele & Zweigle. 7989.
Systems for washing out and re filling locomotive boilers. Groom. 8143.
Lubricating systems. Maranville. 8184.
Condensing plant. Parsons & Cook. 8189.
Drilling appliances. Jones. 8267.
Carburetters for internal combustion engines. Storey. 8287.
Process for cleaning and sharpening files. Goold. 8358.
Armour plates. Gathmann. 8439.
Brake for railway vehicles. Barclay. 8777.
Stuffing-boxes. Crawford. 8898.
Supplying of air to furnaces. Fletcher. 9452.
Valve for internal-combustion engines. Tuckfield, Garland, and Petersen. 9736.
Apparatus for starting internal combustion engines. Mayo. 10467.
Steam engines. McKay. 11026.
Rotary pumps. Wallis. 11990.
Apparatus for treating gas for purification. Chandler & Waller. 12007.
Starting of internal-combustion engines. Stephens. 12316.
Apparatus for making observations on the gas caps of miners' safety lamps. Wolf Safety Lamp Company, and Cremer. 12641.
Point or switch operating mechanism for railways. Lance. 13166.
Friction clutches. Price. 13362.
Motor-vehicles. Lines. 13598.
Nozzles for welding burners. Schweiz Flussiggasfabrik L. Wolf, Akt.-Ges. 14622.
Steam generators. Solomiac & Olier. 14671.
Water-tube boilers. Babcock & Wilcox, Ltd. 15093.
Gearing for the transmission of rotary motion. Royce & Rolls Royce, Ltd. 15333.
Cocks or valves. Potter. 15725.
Method of uniting the ends of rails, girders, and other parts of iron and steel structures. Th. Goldschmidt Akt.-Ges. 16165.
Pumps. Drewett. 16608.
Rotary engines and pumps. Sandreczki. 17350.
Fluid-pressure engines and lubricators therefor. Justice. 17962.
Rotary gas compressors. Elliott & Waller. 18887.
Valve devices for internal-combustion engines. Pollak. 19996.
Compressed-air driven winding, haulage, and like motors. Leroyer. 21694.
Pipe joints. Meyenborg. 21748.
Means for locking nuts. MacDonald. 21847.
Metal-shaping machines. Herbert & Vernon. 22022.
Tube mills. Fennell. 22059.
Priming devices for centrifugal pumps. Maffei-Schwartzkopff Werke Ges. 22625.
Ball bearings. Rennerfelt. 22843.
Furnaces of steam generators. Schleyder. 23057.
Apparatus for relieving compression in internal combustion engines. Tisdell & New Hudson Cycle Company. 23147.
Joints or couplings for connecting branch pipes to main pipes. Westphal. 23347.
Variable-speed gear for motor-road vehicles. Doherty and D. H. K. Motor Cycle Specialities Company. 23519.
Speed-indicating apparatus. Faigle. 23942.
Presses for producing weldless tubes. Hydraulik Ges. 24357.
Pressure indicators. Von Riegen & Lambert. 24568.
Appliances for coupling and uncoupling railway trucks. McEntyre. 24811.
Monoplane. Desaye. 25078.
Cooling internal combustion engines. Kilburn. 25219.
Means for loosening tubes from mandrels in the manufacture of tubes. Westin. 25905.
Rotary slide valves for internal combustion engines. Lentz. 26286.
Ball bearings. Worth. 26566.
Lift valves. Day & Windeler. 28150.
Lifting jacks. Tarpin. 28637.
Systems for starting engines. Kettering. 29070.
Starting systems for internal-combustion engines. Kettering. 29083.

1913.

Heat insulating materials. Arthur. 243.
Ore-dressing apparatus. Velten. 502.
Systems for starting engines. Kettering. 504.
Stabilisators for flying machines. Greer. 984.
Machinery for grinding and polishing metallic rings. Sangster. 1807 and 1808.
Steam steering machinery. Patterson. 2354.
Blade rings for radial flow turbines. Aktiebolaget Ljungstroms Angturbin. 2544.
Method of manufacturing blade rings for steam and gas turbines. Aktiebolaget Ljungstroms Angturbin. 2545.
Steam turbines. Aktiebolaget Ljungstroms Angturbin. 2922.

ELECTRICAL, 1911.

Load equalising arrangements for electric generators. Marks. 29178.

1912.

Means for regulating dynamos. Leitner. 7776.
Telegraphy. Heurtley. 7786.
Electric insulators. Müller. 7972.
Dynamos. Vendervell & Midgley. 8040.
Voltage regulators for electric generators. Olmsted. 8063.
High frequency apparatus. Dubilier. 8196.
Electric telegraph transmitting systems and apparatus therefor. Raymond Barker. 8352.
Automatic signalling arrangement for electric railways. Samaia. 10434.
Electric control systems. British Thomson-Houston Company. 11466.
Systems for the electrical transmission of power and signalling purposes. Hunter & Shand. 13355.
Armoured electric cables. Callender's Cable and Construction Company and Pipkin. 14157.
Trolley heads for electric traction. Parker & Smith. 15022.
Automatic telephone circuits. Siemens Bros. & Co. 18356
Telephone system. Baumann. 18676.
Printing telegraph instruments. Kessels. 21332.
Vapour electric apparatus. Hewitt. 22246.
Telephone receivers. British L. M. Ericsson Manufacturing Company, and Brookes. 22252.
Intercommunication telephone systems. British L. M. Ericsson Manufacturing Company, and Brookes. 22253.
Method of producing high-frequency oscillations. Rottgardt. 22875.
Electric switches. Liddle. 24932.
Telephones. Jensen & Pridham. 25896.
Appliances for producing electric oscillations. Krause. 28595.

1913.

Wireless telegraph installations for aerial vessels. Rouzet. 947.
Arrangement for the static transformation of three-phase alternating current into one phase alternating current having treble the frequency of the primary current. Spinelli. 2471.
Telephone transmission circuit. Egerton. 2749
Electric mercury switches. Gruber. 4297.

Non-ferrous Laboratories at Sheffield University.—The laboratories of the Department of Non-ferrous Metallurgy at the Sheffield Applied Science Buildings, are now almost complete. They will form an important and valuable addition to the work of Sheffield University. The formal opening is to take place on Thursday, May 1st.

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Edited by
WILLIAM H. FOWLER
Wh. Sc., M.Inst.C.E.

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Restriction of Output and its Effect on the Individual.

THE placing of orders for three large British steamers with French firms at Dunkirk has raised a heated discussion in the Press and on the platform. Certain newspapers and individuals roundly assert that these orders went abroad because of the attitude of British shipyard workers in restricting the output from British yards by losing time and generally by adopting the so-called ca' canny, or reduced output policy. The labour press and officials in return stoutly deny that the British workman does any such thing, and assert that the whole agitation is merely a capitalist cry to discredit the trade unions and the wage-earning classes.

In this particular instance both sides have some evidence wherewith to support their cases. On the side of the employers there is evidence that certain sections of the workers lose a good deal of time before breakfast and on Mondays, sometimes balancing this by working overtime. So far as the present discussion is concerned, this lost time seems mainly confined to the shipbuilders; the engineers and indoor men giving little cause for complaint. On the labour side, as above remarked, the lost time seems sectional rather than general, but the sections most guilty are those which most influence the time required to build a ship. The strongest argument of the labour man, however, is the undoubted fact that shipbuilding firms in this country are very busy and have very full order books, in which circumstances the date of completion is necessarily pushed several months further off. Having granted that the British working man is not the impersonation of laziness and meanness, we may dismiss the three French-built ships. There remains, however, the whole question of restricting output, and it is desirable to face this, one of the most perplexing problems of modern industry.

Restriction of output does exist. Sometimes it takes the form of widespread refusal on the part of the workmen to put forth their best efforts, or, as it is often put, the men ca' canny. In America they call it soldiering, which is perhaps a reminiscence of military life in that hustling land. At

other times local bodies of workpeople, with or without the official support of their unions, resist and hinder methods of working which are calculated to increase the output or reduce the cost of production. In some cases these methods extend over a wider field and a whole union is up in arms against some innovation designed to reduce or cheapen labour costs. Every responsible works engineer is constantly coming across instances of restriction such as outlined above. Except in the case of the larger disputes they seldom come before the public, and to a greater or less extent are, indeed, officially condemned by the trade unions.

The secret causes of this widespread limitation of output are the two natural, and in themselves legitimate, desires on the part of the workmen to avoid doing another man out of his job, and also to always leave sufficient work for himself to do. The workman thinks that there is, roughly, only a certain amount of work to be done. Hence if anyone does more than his share some one else will be done out of a job, and if, on the other hand, all alike speed up their work they will all find themselves on short time and short pay to correspond. If this argument is true the worker is justified in his restrictive attitude. Is it wholly true, and if not wholly true, is it partly true? That is the question, or questions, to which serious attention should be directed. If the British workman can be convinced that there is plenty of work for all, most of the annoying and harmful interference and antagonism which works managers suffer at the hands of the men will disappear. One may tackle the problem in two ways: By an appeal to history—that is, to experience—or by an appeal to reason.

Let us consider the verdict of history. There have been alternate periods of good and bad trade, and will be in the future, but, speaking of the average demand for labour, there is certainly no sign of any slackening now as compared with 25, 50, or 100 years ago, although in these intervals there has been a rapid increase in the amount of work, as measured by production, which a man can do. To take a few examples: Screws were formerly made either by hand or by skilled artisans with a certain amount of machine assistance. To-day they are made in vast quantities by automatic machinery. The demand for screws has not stood still. On the contrary it has expanded enormously, and, owing to the cheapness with which screws are now made, they can be used in many cases where formerly they were too expensive, thus benefiting other workers as well as the screw-makers. No one, indeed, would suggest that labour would be benefited if we could go back to the ancient methods of making screws. An even more striking example is furnished by the printing press. When books were hand-printed or written and hand-made they were the treasures of the very rich. Only when the letters were reproduced mechanically by type did the blessings of books come within reach of even the middle classes. Further and more recent improvements in the printing and making-up of books have placed almost all literature, technical and otherwise, within reach of the working-man. One man can produce many times as much printed matter as formerly. Yet the demand for printers has increased, and we are not in sight of the end of the increasing demand for literature.

Leaving individual examples and surveying the field of industry as a whole, the average proportion of unemployed is not increasing. Of that there is no room to doubt; the evidence is too complete. And yet the individual is to-day producing more than ever in the past. Why, then, should we imagine that further increases in producing power will reduce the demand for labour? The verdict of history being unmistakably against the assertion that increase in productivity and industrial efficiency will make for unemployment, let us review the logic of the arguments on both sides.

Why should there be a limit to the amount of work to be done in the world? Work is necessary just in proportion to the demands of people, rich and poor included, for food, clothing, travel, reading, amusements, and all other things which cost money. Has the world enough of all these things, or even of any one of them? There can certainly be only one reply. Some of us have enough food, although most of us would like better food—that is, food which requires more labour of one sort and another to produce. The same applies to clothing, although there are many people who would be glad of more of both food and clothing, apart altogether from any improvement in its quality. If we turn to the less immediately urgent necessaries of life, we none of us are satisfied, but are all insistently seeking for more. A New Englander put the whole matter concisely when he said that he had twice the income of his father, but 20 times his wants. This, indeed, is the conclusion of sociologists and politicians of all opinions: That the demand of the people for the things which cost money is increasing more rapidly than the incomes out of which the purchases have to be made.

In fact, the problem of the future is not to find markets for the swelling outputs of our fields, factories, and mines, but to curb the demands of the people within the limits which can be supplied. We need not fear that we shall "do another man out of his job," but unless we strenuously increase industrial efficiency by reducing labour costs we shall certainly narrow and stunt the lives of the people, particularly the poorer classes. They are the chief sufferers from the warm-hearted but mistaken ca' canny policy.

One other point should be touched upon. Trade is not always good. Industry is built up on human understandings. Often these go astray. One section over-estimates the demand of humanity for its products and there comes a slump. The people do not buy and the workers go short in wages. Or, again, misunderstanding, coupled perhaps with dishonesty in places, leads to an industrial mistake or miscalculation. Confidence, the cement of all human relationship, is shaken and there is a lull in new enterprises; perhaps even a panic. Or, again, it occasionally happens—although more rarely than most people think—that a change in industry comes suddenly and displaces labour. Except for a few old or unfortunate ones, such displacement is only temporary. It is none the less painful on that account, and demands the earnest attention of sociologists; but it must not be allowed to obscure the urgent need of the whole people, but more particularly the poorer classes, for a higher standard of living; and this can only be secured by a steady and persistent speeding up and increase in the efficiency of the industrial machine. More, ever more, is the great need.

Death of the Inventor of Interlocking Railway Points.—Mr. John Saxeby, inventor of interlocking railway points and signals, died last week at Hassocks, near Hayward's Heath, at the age of 91. He was born at Brighton in very humble circumstances. For over 22 years he worked for the Brighton Railway Company, and brought out a signalling lamp which gave twice the light of those in use. For this the company gave him £50. Fame and a fortune of £200,000 came to him through his invention of interlocking railway points and signals. Prior to this invention many accidents were due to the changing of points while a train was passing over them, but with Mr. Saxeby's invention there came into existence a mechanical reciprocating communication and action between all the points and signals at a railway station. The first signal of the type was erected at Keymer Junction, near Hayward's Heath. Mr. Saxeby started in business, and as railways rapidly recognised the value of his invention he ultimately employed some 3,000 hands.

QUADRUPLE SCREW TURBINE-DRIVEN ALLAN LINER "CALGARIAN."

BUILT BY THE FAIRFIELD SHIPBUILDING AND ENGINEERING CO., LTD., GOVAN.

THE launch of the "Calgarian," the latest addition to the large fleet of the Allan Line, took place on Saturday, April 19th, from the yard of the Fairfield Shipbuilding and Engineering Company. She is sister ship to the "Alsatian," launched a few weeks ago on the Clyde, and will share with that vessel the distinction of being the largest and most magnificently appointed liner in the Canadian trade. It is peculiarly fitting that this should be the case, for the Allans pioneered this trade, having sailed the first craft, the brigantine "Jean," of 169 tons, from Glasgow to Quebec, as far back as June, 1819. From that early and auspicious, if comparatively insignificant, beginning has been built up a fleet and a reputation that might well be envied. Not only has the flag been carried by progressive steps from a craft of less than 200 tons to one of more than ten times her size, but it has floated over epoch-making ships representative of some of the most important changes that have taken place in the history of the world's mercantile marine. The first steamship to engage in this trade to carry out the first mail contract entered into by Canada was the "Canadian," built in 1853, and this contract has been entrusted to Allans ever since. The total fleet of the Allan Line registers materially over 200,000 tons to-day.

The new ship, together with the "Alsatian," will be employed in the main mail service between Liverpool and the St. Lawrence. She is externally exactly like the "Alsatian," excepting the decorations of the passengers' quarters. The "Calgarian" is a four-screw vessel, 590ft. in length, 70ft. in beam, and 54ft. deep to the bridge deck, of a gross tonnage of about 18,500, and a speed at sea of 18 knots. Special consideration has been given to the question of subdivision, and so numerous are the water-tight bulkheads and decks that, under ordinary circumstances, any four compartments could be thrown open to the sea without serious risk of foundering. The bulkheads in the engine and boiler spaces have doorways through them for ease of communication and to facilitate control; each of these openings is fitted with a "Stone-Lloyd" door, which closes automatically in case of flooding of the adjoining compartments; they can also be closed from the bridge by the officer in charge. The large measure of safety thus secured is added to by the provision of a double bottom extending well up the bilge. In case of ultimate necessity, however, there is a full provision of boats for all, together with a life jacket for every person on board. Like the Canadian Pacific liner "Empress of Russia," at present on her maiden voyage to Vancouver, the new vessel has a straight stem and a cruiser stern, with an overhung and submerged rudder. This form of stern was severely tested during the official trials of the "Empress of Russia" and earned unqualified approval on account of its excellent qualities as regards freedom from vibration, steadiness and ease of steering, and efficiency of propulsion. In addition to the usual light and sound signals and a powerful installation of wireless telegraphy, the "Calgarian" is provided with a submarine signalling apparatus which enables the ship to ascertain the relative position of any ship or station similarly equipped, even when invisible on account of fog or other cause.

In order to provide the power necessary for lighting, heating, ventilating, cooking, working forced draught fans, lifts, hoists, and all the miscellaneous services now required, three turbo-driven generating sets are fitted, each of 250 kw. capacity; and as a stand-by in case of a complete breakdown of the main plant, an 18 kw. turbine-driven generating set is installed on deck, well above the water line. A refrigerating plant of large capacity is provided, which supplies the large cargo chambers as well as the ship's cold stores.

The propelling machinery consists of four turbines of the Parsons type, embodying the most recent improvements in design and construction to ensure the maximum economy in fuel consumption, and resembling in this respect the "Empress of Russia" and the "Empress of Asia," recently constructed by the same builders. The port wing shaft is driven by a high-pressure turbine exhausting into an intermediate-pressure turbine driving the starboard wing shaft. The two inner shafts are each driven by a low-pressure turbine which has a powerful astern turbine incorporated in the same casing. For manœuvring when entering or leaving harbours, independent high-pressure steam connections are provided on each low-pressure ahead turbine. There is also an independent high-pressure steam connection to the intermediate-pressure turbine which, combined with a suitable arrangement of valves, enables the high-pressure turbine to be cut out, or should the intermediate-pressure turbine be out of action, the high-pressure turbine can exhaust direct into one or other or both of the low-pressure turbines.

The whole of the main propelling and auxiliary machinery is situated in one water-tight compartment. The condensing plant ensures the maintenance of the high vacuum essential for economy with turbine machinery. It consists of two condensers of the Weir uniflux type, four circulating pumps of large capacity, and two Dual type wet and dry air pumps. The circulating pumps and air pumps form two distinct and

separate sets, each set working in conjunction with one condenser, and independent of the other, but are so arranged with suitable cross connections that either set of pumps can, if required, work in conjunction with both condensers. The installation of auxiliary machinery is exceptionally large, and it also has been designed to secure the greatest economy in fuel consumption with convenience in working. The feed-water system for the boilers comprises two twin filters of the gravitation type, through which the water from the air pumps is discharged on its way to the feed tanks; four feed pumps discharge through a surface feed water heater direct to the boilers. The feed-water is heated by the exhaust steam from the auxiliary machinery, the waste steam from ship's heating and drainage systems and from steam pipes throughout the ship. This system, the result of careful consideration, will ensure that all waste heat from the auxiliary steam and exhaust systems is utilised in heating the feed-water instead of being carried away by the circulating water from the condensers.

For harbour use, a separate auxiliary condenser with circulating pump, air pump, feed filter, and feed pump is fitted to admit of the corresponding auxiliary machinery used on service being opened out for cleaning and examination. All bearings for the turbine and line shafting are connected to the forced-lubrication system and the supply is maintained by four large pumps which discharge the oil through special coolers before entering the bearings. Separate pumps are fitted for circulating cold sea water through the oil coolers. The pumps for ship's use include general service pumps, sanitary hot and cold water pumps, bilge pumps, fresh water pumps, ballast pumps, and two Stone-Lloyd pumps for the water-tight door hydraulic closing gear. The distilling machinery is also situated in the main machinery compartment and consists of two large evaporators, and four fresh water distillers with the necessary independent pumps.

Steam is generated in six large double-ended and four single-ended boilers situated in two separate compartments and working under the Howden system of forced draught. The air supply is maintained by an installation of electrically-driven fans. In order to overcome the rapid deterioration which frequently takes place between the time of lighting the fires and the raising of steam, owing to the unequal expansion of the internal and external parts of the boiler, a special device of the Allan Line Company's superintendent engineer's has been fitted, which, by causing a continuous circulation of the water, ensures a uniform temperature throughout the boiler. For dealing with the ashes at sea, See's ash ejectors are fitted in each stokehold, and in each boiler compartment a specially designed ash ejector pump for supplying the water under pressure to the ejectors is fitted. Two Crompton's silent ash hoists are also fitted in each boiler compartment for harbour service, in order to avoid the noise which is frequently objected to when ash-hoisting machinery is used in the vicinity of the passengers' quarters.

The total complement of the "Calgarian" is about 2,100 persons, of whom about 200 are first class, 450 second, and 1,000 third-class passengers, the crew numbering some 450.

Launch of the Cruiser "Nottingham."—The light cruiser "Nottingham," the 13th vessel of the "City" class to be put afloat for the British Navy, was launched at Pembroke Dockyard on the 18th ult. Her first keel-plate was laid on June 13th, 1912, and she is expected to be completed in March, 1914. Her principal dimensions are: Length, 430ft.; extreme breadth, 49ft. 10in.; mean load draught, 15ft. 10in.; and displacement, 5,400 tons. The vessel will be protected by side armour consisting of an outer belt of nickel steel and an inner belt of high-tensile steel, of a maximum thickness of 3in. The propelling machinery, which is being constructed by Messrs. Hawthorn, Leslie, & Co., of Newcastle, will consist of twin turbines, developing 25,000 h.p., giving the vessel a speed of 25·5 knots. There will be 12 Yarrow water-tube boilers, four in each of three stokeholds. In addition to coal bunkers with a maximum capacity of 650 tons, she will have accommodation for oil fuel. The main armament will include nine 6in. guns, or one more than in the Chatham class of the previous year's programme, and there will also be two 21in. torpedo tubes. The complement will number 400 officers and men.

SELF-SYNCHRONISING MACHINES.*

BY DR. L. ROSENBERG.

(Concluded from page 430.)

SELF-STARTING ROTARY CONVERTERS.

ROTARY converters are frequently started, like squirrel cage motors, from low voltage tappings on the transformers. In general, the procedure is the same as that described for synchronous motors, but there are two or three aggravating conditions. There is a commutator with brushes always short-circuiting a certain part of the armature winding, and the field winding is not excited from an outside source, but generally from the continuous-current brushes of the rotary converter. Commutating poles are frequently added, which fill part of the space between the main poles, their tips not being fitted with dampers like the tips of the main poles.

The short circuiting of one part of the armature winding will naturally reduce the torque for a given starting current, or will increase the starting current required for a given torque. It also causes sparking during the starting period.

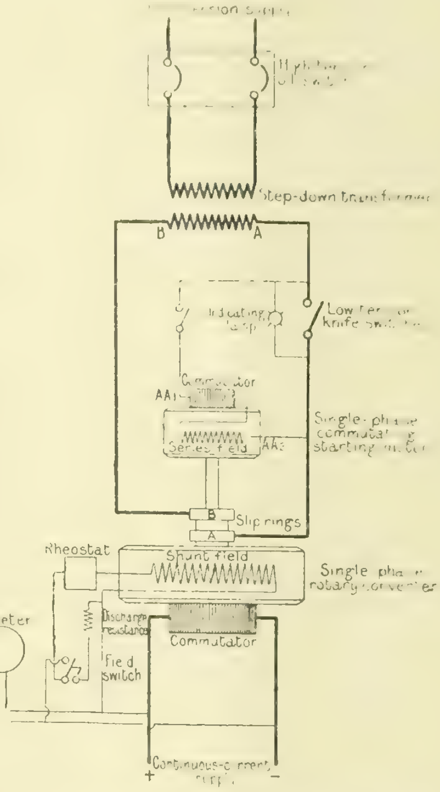


FIG. 8. DIAGRAM OF CONNECTIONS OF SELF-SYNCHRONISING SINGLE-PHASE ROTARY CONVERTER WITH STARTING MOTOR.

If we assume a distance of 10in. from brush arm to arm and a brush thickness of 1in.—a ratio which from the point of view of commutation might be quite permissible—we would have practically one-tenth part of the pole arc of the armature winding short-circuited under the brushes. In a 600-volt continuous-current machine (425 volts diametrical alternating-current voltage) which is started with one-third to half of full voltage, windings with an electromotive force of 14 to 21 volts alternating current would be short-circuited by the brushes if the voltage was evenly divided around the armature. In a machine without interpoles, the "short-circuited voltage" is lower, but in a machine with interpoles it will be even higher than the above-mentioned value. It is an alternating-current voltage of full frequency at first, and later on of reduced frequency. Designers of alternating-current commutator motors know that even with a considerably lower voltage than 15 to 20 volts under the brushes it is necessary to use resistance leads in order to prevent violent sparking at the brushes, and that the brushes are generally reduced in thickness as much as possible in order to reduce the voltage under the brushes to a far lower value. Naturally, also, the brushes of rotary converters which are started

* Paper read before the Manchester Section of the Institution of Electrical Engineers.

in this way are very liable to spark, and it is necessary to reduce the ratio between the brush thickness and the distance of brush arms to a considerably lower value than would be required to obtain good commutation when working with continuous current on the commutator. The most violent sparking occurs as a rule when approaching synchronism. The armature then tries to hang on first to one pole until it comes to the fringe of the field, and then jumps in a jerk to the other pole. This jerk means magnetically that one pole, which up to then was excited from the armature in one direction, is suddenly reversed. The coils which are short-circuited through the brushes are traversed by the whole magnetic flux flowing from one pole to another, and the sudden reversal causes a heavy electromotive force in the short-circuited winding, as the electromotive force is proportional to the momentary change in flux (differential value of flux time).

It is not permissible to fit dampers on the tips of the commutating poles as is done on the main poles. When working in regular service with continuous current, the commutating pole should vary its flux as quickly as possible with the changes in the line current to provide the proper commutating field for every momentary value of the armature current. If a damper were fitted to the pole-tip this would prevent sudden changes of the flux, and would make the commutating pole sluggish, and the machine would therefore have a tendency to flash-over with sudden changes of load. We have now during the starting period a certain current flowing through all turns of the armature winding. Under the main poles the magnetising action of the armature current is counteracted by the opposed induced currents in the damper. Under the commutating poles there is no damper and no counteraction. The field density under the commutating pole would therefore be far greater than the field density under the main poles. An induction motor with complete squirrel-cage secondary shows no tendency to run at half speed. A single axis secondary winding, however, shows a distinct tendency. A secondary winding which is only confined to a distinct part of each pole arc, and allows a strong field to be established in other parts of the arc of the secondary, will have the same influence. The machine, running at half-speed, will induce in the secondary a half-frequency oscillating field, which, replaced by two opposed rotating fields of half-frequency, explains the possibility of the machine remaining stationary at half-speed, or the distinct reduction of the torque at this speed. In order to prevent this it is necessary to provide during starting a damping winding on the commutating poles, and this is achieved in the simplest way by short-circuiting the commutating pole winding during starting and opening the short-circuit before switching the machine on to the continuous-current mains.

A rotary converter started from low-voltage tappings requires considerably more than full-load armature current, even if barring gear is provided to take care of the initial starting friction, or if ball bearings are used. For the line this may represent only part of the full-load current, due to the reduction in the transformer; but in the rotary it will generally cause the extinction of the residual magnetism of the poles, and when the machine locks into synchronism it may show either the right or wrong polarity. Therefore pole-changing devices are always provided for rotaries started in this way, which, if the wrong polarity is obtained, give an opportunity of making the machine slip one pole and obtain the proper polarity.

The sparking on the brushes is as a rule the more objectionable the higher the output and the frequency of the rotary, and it would of course be more objectionable with higher voltages if brushes of the same thickness were used as with lower voltage. If the sparking is not too violent, and if the rotary is only rarely started, say, once a week, or once a day, the polish of the commutator and brushes, which is spoilt to a certain degree during starting, will again be established during ordinary working with continuous current, and therefore this method has been adopted by many makers as standard for certain sizes. For large sizes, however, either outside synchronising devices are adhered to, starting being effected either from the continuous-current side or by means of a starting motor, or brush-lifting devices are introduced to overcome the sparking. As a rule only one positive and one negative brush are left on the commutator so as to enable the operator to recognise the polarity to which the machine excites itself, and to change it by pole-slipping if necessary.

A brush-lifting device used with multipolar machines with many brushes per arm represents a great mechanical complication.

SELF-SYNCHRONISING USING A STARTING MOTOR.

A new method introduced by the author allows self-synchronising of the rotary converter with small armature current, prevents sparking on the brushes, and prevents the reversal of the field of the rotary converter. A starting motor is connected in series with the slip-rings of the rotary converter. As a starting motor, an ordinary squirrel-cage polyphase motor is nearly always used, but the explanation of the method is perhaps simplest by assuming a single-phase rotary converter and a single-phase commutator motor for starting (as in Fig. 8). There are no starting tappings on the main transformer. One low-voltage terminal, B, of the transformer is connected direct to one slip-ring, B, of the rotary converter, while the other terminal, A, has a straight connection through a single-pole main switch, and another connection if the main switch is open through the single-phase

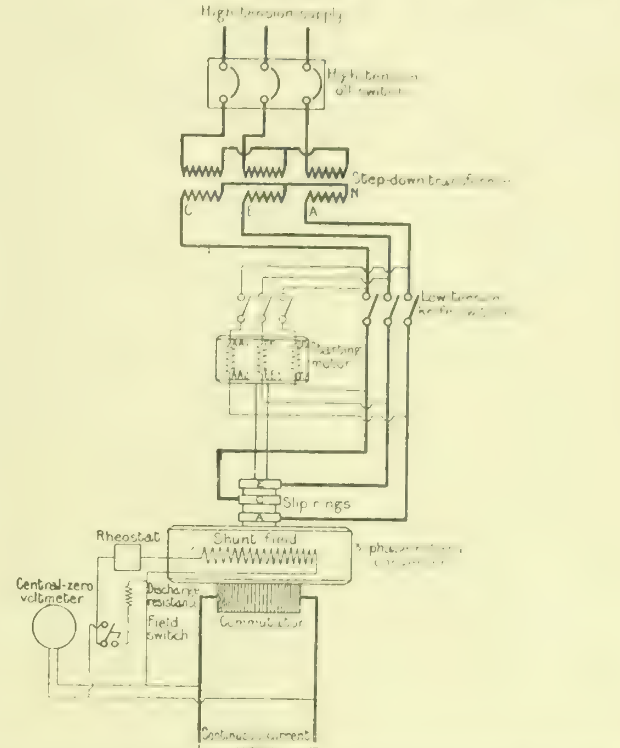


FIG. 9. DIAGRAM OF CONNECTIONS OF SELF-SYNCHRONISING THREE-PHASE ROTARY CONVERTER WITH STARTING MOTOR.

starting motor. A small switch is shown in series with the single-phase motor, but is not essential.

If the high-tension switch of the transformer and the switch of the starting motor are closed, the main low-tension switch being open, the current will flow through the starting motor into the rotary converter. The starting motor limits the current to a fraction of the full-load current of the rotary. The rotary armature represents very little impedance. Assuming, for instance, that for full-load current in the rotary the voltage across the slip-rings would be 20 per cent. of the normal voltage, then, if the starting motor is designed so as only to allow 30 per cent. of full-load current to pass through the rotary, the voltage on the slip-rings will be reduced to 6 per cent. of the full-load voltage. The starting motor takes practically the full voltage of the transformer terminals, and as with a properly designed rotor this current of 30 per cent. can produce a very good torque which is far in excess of the starting friction, it will, without any barring, start and bring the rotary up to speed very quickly. A current of this value is, as experience has shown, not sufficient to destroy the residual magnetism of the rotary converter. The field circuit of the rotary converter remains connected across the continuous-current brushes, and the rheostat is preferably put into such a position as to reduce the inserted resistance slightly below the value required for normal no-load excitation, as is done for instance with ordinary continuous-current shunt wound machines in order to allow

quick excitation. As soon as it approaches synchronism, the machine will therefore readily excite itself like any other continuous-current machine. This gives on the slip-rings an alternating current of a frequency which at first is slightly different from the transformer frequency.

Assuming that the rotary has excited itself to full voltage, then immediately before slipping into synchronism the voltage

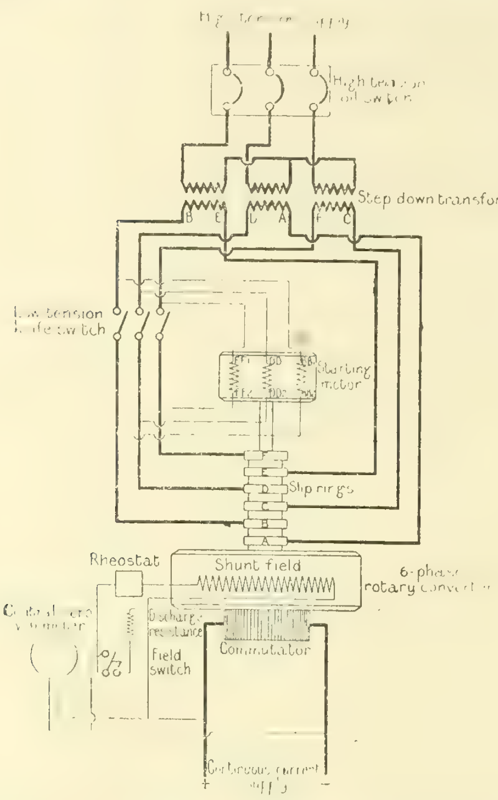


FIG. 10.—DIAGRAM OF CONNECTIONS OF SELF-SYNCHRONISING SIX-PHASE ROTARY CONVERTER WITH STARTING MOTOR

on the starting motor will vary from zero to double slip-ring voltage, and as the current flowing through the starting motor has, of course, some influence on the rotary converter, the continuous-current voltmeter will show violent fluctuations. Immediately the rotary has slipped into synchronism, this voltmeter will be steady; the voltage can then be adjusted, and the main single-pole switch which short-circuits the starting motor can be closed. The rotary would be in synchronism before the switch was closed, and being excited to full voltage the closing of the switch causes neither a heavy rush of current nor any sparking at the commutator. Across the main low-tension switch an indicating lamp can be fitted as shown in Fig. 8. This lamp will flicker before synchronism is reached, and will be dark after the rotary has slipped into synchronism. Attendants who are used to the old method of synchronising become more easily accustomed to the new method if they see the working of the indicating lamp. In general, however, the continuous-current voltmeter gives full indication of synchronism. It is quite easy to understand that, with a starting current as mentioned, no reversal of the field polarity takes place; while with "self-starting" rotaries this occurs frequently.

A moderately saturated continuous or alternating-current machine will show, unexcited, a voltage, due to residual magnetism, of approximately 1 to 2 per cent. of full voltage. The field can be considered as the seat of a magneto-motive force nearly equal to 1 or 2 per cent. of the field ampere-turns which are required to send the full voltage flux through the field, air gap, and armature. If we impress on the slip-rings of a self-starting rotary converter an alternating-current voltage equal to 33 or 50 per cent. of full voltage, we create a flux of 33 or 50 per cent. and excite the machine from the armature with a number of ampere-turns slightly less than 33 or 50 per cent. of the normal field ampere-turns. About nine-tenths of this magneto-motive force will be absorbed in the air gap and the iron of the armature. One-tenth of it, viz., about 3 to 5 per cent. of the normal field ampere-turns, is consumed in the field iron. The coercive force of the field is smaller, viz., 1 to 2 per cent., and therefore the magnetism of each pole will be reversed every time the rotary "slips a pole." If, on the other hand, a series-connected starting motor limits the voltage impressed on the rotary slip-rings to 6 per cent., the magneto-motive force impressed on the field is only about ½ per cent. of the normal field ampere-turns, and is not able to reverse the residual magnetism, which represents nearly 1 to 2 per cent.

Fig. 9 shows the self-synchronising arrangement for a 3-phase rotary converter in series with a 3-phase squirrel-cage motor. No indicating lamp is here shown. Fig. 10 shows the connections for a 6-phase rotary converter. By using a slip-ring motor the starting current could be kept even lower than 30 per cent.; and the impedance of the starting motor could be reduced, when the rotary is in synchronism, by short-circuiting the rotor of the starting motor. The simple squirrel-cage rotor, however, is preferred in most cases. In Figs. 8, 9, and 10 a single-pole field switch with discharge resistance is used. It is possible to keep the field switch open during starting, which will allow the rotary to approach synchronism in an even shorter time than with a closed field switch. When the rotary passes through synchronism, one can observe on the continuous-current voltmeter, which is shown in Figs. 9 and 10 as a central zero voltmeter, one oscillation from a small positive to a small negative value, or vice versâ, for every slipping of one pole. By putting this field switch in at the moment of proper voltage indication, the machine will build up immediately to full voltage, and remain in synchronism.

With starting motors, allowing approximately 30 per cent. of full-load current, the whole starting and synchronising is completed in less than one minute, and the rush of current in short-circuiting the starting motor does not exceed the starting current, that is, 30 per cent. of full load. Various tests with 50-cycle rotaries of 200 kw. to 1,000 kw. gave as the time necessary for starting and synchronising 30 to 50 seconds, the current not exceeding at any moment of the starting period one-third of the full-load

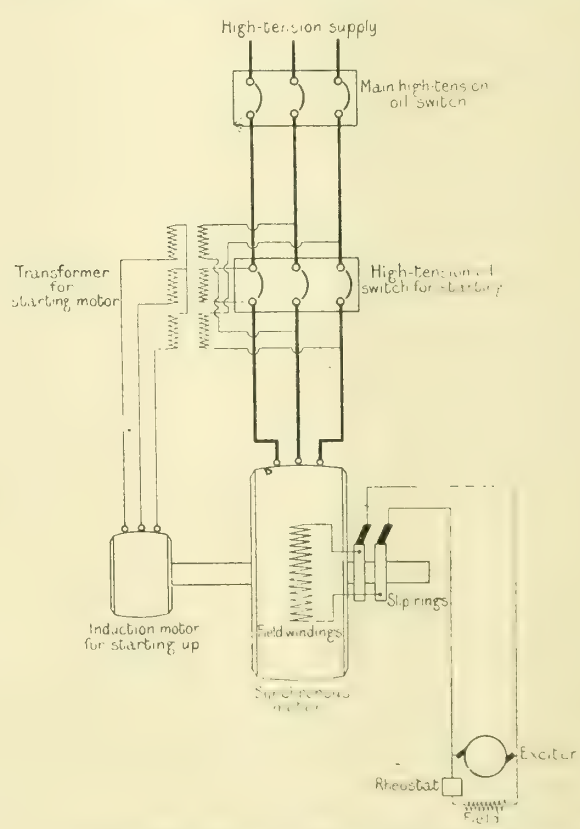


FIG. 11.—DIAGRAM OF CONNECTIONS OF SELF-SYNCHRONISING HIGH-TENSION THREE-PHASE MOTOR WITH STARTING MOTOR.

current. By connecting the windings of the starting motor in a different way, and allowing a starting current of 50 to 60 per cent., it was possible to start in 15 to 20 seconds. Such a current, however, may destroy the residual magnetism, and therefore it is necessary in such cases to use the field switch shown in Figs. 8-10, and to close it at the moment when the

polarity of the unexcited machine is such as to ensure building up in the right direction.

It will be evident that there is no tendency for sparking during the starting period if a very low alternating voltage, such as 6 per cent. of the normal, is impressed on the slip-rings. Let the commutator brushes short-circuit 10 per cent. of this voltage. This means with a 600-volt rotary an alternating voltage of $0{\cdot}6 \times 4{\cdot}2 = 2{\cdot}5$ volts; that will not cause sparking. Although with the field circuit closed the field strength is considerable before slipping into synchronism, there is only a small alternating field superimposed upon the field of constant direction, and this small reversing field is of course quite harmless. The series connection of starting motor and synchronous machine can, of course, also be used for synchronous motors.

For high-tension synchronous motors, a low-tension starting motor presents advantages. For this purpose an indirect series connection by means of a series transformer can be used (Fig. 11). The primary windings of the transformer are connected across the lower switch shown in Fig. 11; the secondary winding is connected to the starting motor. For starting, the lower switch is open, and the upper switch closed. After the machine has pulled into synchronism, the lower switch is closed, thereby short-circuiting the primary windings of the transformer. No current will then flow either through transformer or starting motor, although the primary windings of the transformer remain alive.

Such a "self-synchronising" series arrangement may appear considerably more complicated than the "self-starting" of the high-tension motor itself as a squirrel-cage motor by means of an auto-transformer. This, however, is hardly the case. The auto-transformer required for self-starting is of nearly the same size as the transformer for the starting motor in the self-synchronising method of Fig. 11. With the self-starting method we also have voltage surges in the end turns of the windings of the synchronous motor when we switch over to the full voltage. Momentary rushes of current also occur here, first in switching on to the low voltage, and more particularly in switching over to the full voltage. These rushes are a very serious drawback, and cause sudden movements of the winding, which may have a detrimental effect on the life of the insulation. If precautions were taken to avoid these jerks, either by resistances or multi-step switches, the addition of the necessary apparatus would make the gear more complicated than the gear of Fig. 11.

In the arrangement of Fig. 11 when starting, the voltage surges are taken up by the transformer and not by the motor windings. The transformer windings are far better suited for this function. Before short-circuiting the starting transformer, the motor has already full voltage on its terminals. No voltage surge should therefore occur at the moment of short-circuiting. The current rushes at the moment of switching in and at the moment of short-circuiting the starting transformer are only a fraction of full-load current. It therefore seems justifiable to use this method of starting for synchronous motors, although it was primarily designed for use with rotary converters. It is easy to provide in connection with the starting transformer a few turns which remain permanently in circuit and protect the motor winding against voltage surges occurring during normal work.

In a self-starting synchronous machine, the induction principle brings the machine up nearly to synchronous speed, and the synchronising action does the rest. Also with the self-synchronising method it is possible to do this and to use the same number of poles on the starting motor as on the synchronous motor. The starting motor would then have finished its work by starting the set up to a speed slightly below synchronous speed, and would leave the synchronous machine to do the rest to raise the speed to synchronism. There is no objection, however, to using on the direct-coupled starting motor a smaller number of poles than on the main motor. The starting motor then brings the set up to full speed much more quickly, and if the exciting circuit is closed, with the proper resistance, the synchronising action of the machine will prevent the starting motor from running through the synchronous speed. If the excitation circuit is not closed, the starting motor will run up to a higher speed, but a later closing of the exciting circuit will soon reduce the speed and cause synchronising. It is of very little importance to design the rotor of the starting motor for any exact slip, as a very wide margin is allowed.

If a rotary converter is fitted with an alternating-current booster, it is possible to provide the booster with a separate starting winding consisting of many turns of comparatively thin wire, and, leading these to separate slip-rings or terminals, use the booster like a squirrel-cage starting motor with the same number of poles as the rotary converter. The method can be used in special cases. In general it will not be advisable because the starting winding with many turns would give comparatively high voltage during running, and the breaking up of the starting winding to prevent higher voltage during running would generally be only permissible in the case of stationary armatures.

VOLTAGE DISTRIBUTION BETWEEN SYNCHRONOUS MACHINE AND SERIES-CONNECTED STARTING MOTOR.

It is of great theoretical interest to consider the voltage distribution between starting motor and synchronous machine before the starting motor windings have been short-circuited, but after the machine has locked into synchronism. It is permissible to vary the excitation of the synchronous machine up or down to a very great extent without bringing the machine out of step. The starting motor, if arrangod with fewer poles than the synchronous machine, works with a slip fixed by the synchronous machine, and therefore is forced to give a mechanical output entirely dependent, and within

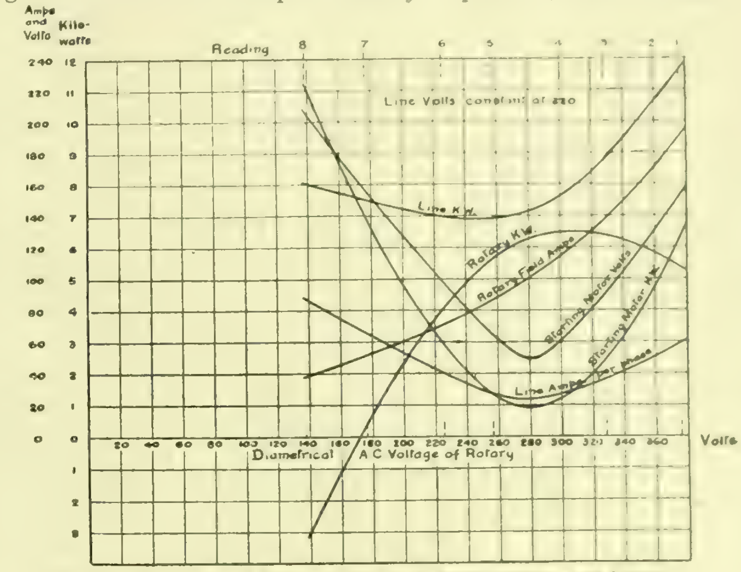


FIG. 12.—VARIATION OF CURRENT, VOLTAGE DISTRIBUTION, AND INPUT, WITH CHANGE OF ROTARY EXCITATION.

certain limits proportional to, the square of its terminal voltage. The phase angle between voltage and current in each phase of the starting motor is, with the fixed slip, nearly constant within certain limits of the impressed voltage. The starting motor has here also the function of an impedance coil (reactance coil with appreciable ohmic resistance) inserted between the supply and the synchronous machine. A change in the excitation of the synchronous machine will change the voltages of both the synchronous machine and of the starting motor.

The input necessary to defray the total losses and the mechanical work done by the set can be divided up, according to the excitation of the synchronous machine, in different ways between the starting motor and the synchronous machine. We can impress such a small voltage on the starting motor that it contributes very little to the total torque of the set, and so that practically all the torque is developed by the synchronous machine. We can, on the other hand, by under- and over-exciting the rotary converter, impress a high voltage on the starting motor. Thus the starting motor does nearly all the work. If the starting motor is amply dimensioned, it is even possible to make it do more work than is required for driving the set. Then the synchronous machine works as a generator or brake preventing the set from running above synchronism. This is very clearly illustrated in Fig. 12, giving the test results of a 1,000 kw. 12-pole rotary converter for 500 volts (direct current) coupled to a 10-pole starting motor. The rotary is a 6-phase machine, connected according to Fig. 10. The voltages were measured for one of the three

distinct phases of the supply, and also across one phase of the starting motor and across the rotary slip rings connected to electrically diametrical points of the rotary armature.

For this test the stator coils of the starting motor were grouped in a special way so as to give a very high torque, and it was possible to change the excitation of the rotary converter between such wide limits (from 9·5 to 1·9 amperes, the normal no-load excitation being approximately 6·3 amperes) that during the last few tests the wattmeter across the starting motor showed actually more input than the wattmeter across the supply, and the rotary converter wattmeter actually reversed, showing that the converter really acted as a generator. It must be mentioned that with very low excitations the instruments were not steady, but the machine still remained in step. Only by reducing the field current below 1·9 amperes did the starting motor pull the rotary above synchronism.

Fig. 13 shows the vector diagram of the supply, rotary, and starting motor voltages for different excitations. The consequent readings with ever-decreasing excitation are marked 1, 2, . . . 8 in Figs. 12 and 13. Reading 1 was taken with 9·5 amperes excitation. In Fig. 13 O A represents the vector of the supply voltage, O 1 the voltage of the rotary converter, 1 A the voltage on the starting motor for reading No. 1. For readings 1 to 5 the vector of the rotary is lagging behind the supply. For reading 6 to 8 the rotary vector is leading. If the starting motor were a mere choke coil, the current through the system would be nearly at right angles to the Vectors 1 A, 2 A, &c., and 6, 7, 8 would represent positions where the rotary acts as a generator. Here, however, the angle between current and starting motor voltage is much smaller than 90°, and the rotary is not acting as a generator in positions 6 and 7, but only in position 8.

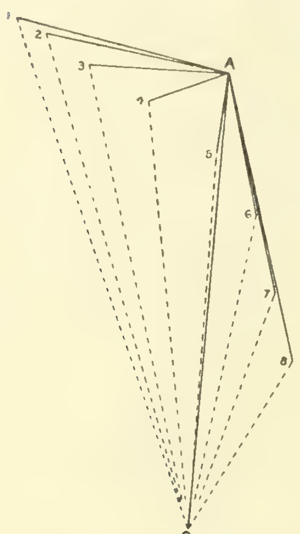


FIG. 13. RELATION OF SUPPLY, ROTARY, AND STARTING MOTOR PRESSURES.

As mentioned above, to achieve these tests the stator winding of the starting motor was specially arranged, and the rotary could be started and synchronised in a small fraction of a minute. The starting current with this arrangement amounted to approximately 450 amperes, or 45 per cent. of the normal rotary current. After re-connecting the windings to the normal position the starting current was approximately one-half of this amount, and synchronising could be achieved in just under one minute. With the proper connections no attempt was made to reverse the wattmeter reading on the rotary converter, but in that case also the field current could be varied between 8·25 and 2·5 amperes without throwing the rotary out of step.

The rush of current at the moment of short-circuiting the starting motor is smallest when the rotary converter is excited to a slightly lower voltage than the line voltage. However, even with the starting motor excited to the full-line voltage, the rush of current is lower than the starting current if the starting motor is dimensioned for approximately 30 per cent. starting current and has the proper rotor resistance. Great latitude is possible in either direction without causing too great a rush of current, without causing any visible sparking on the brushes at the moment of short-circuit, and without affecting the line voltage. If the rotary is excited to full voltage, or slightly over-excited, the line voltage even has at the moment of short-circuiting the starting motor a tendency to rise slightly and not to drop, which can be quite clearly observed if the generator or transformer supplying the current has a poor regulation.

The tests here described, and many other similar tests, were largely carried out on the synchronous motors by Mr. R. Townend, and on the rotary converters with starting motors by Mr. F. C. Aldous and Mr. S. G. Nottage, and by Messrs. Nicholson, Embleton, and Thomasson. My best thanks are due to these gentlemen, and also to Messrs. Batemann, Townend, and Nottage for their help in preparing the diagrams.

IMPROVEMENTS IN WATER-TUBE BOILERS.

To prevent disturbance in circulation of a water tube boiler of the type having at some distance below the bottom tube of the boiler an extra series of tubes connected into the boiler circulation, the Babcock & Wilcox Company, of New York, have recently patented the arrangement illustrated, Fig. 1 being a central longitudinal section through the boiler, and Fig. 2 a detail vertical section on the plane of the line X - X of Fig. 1.

As shown, the boiler comprises a bank A of inclined tubes connected to front and rear headers respectively. This bank of tubes is divided by transverse baffles to provide passes for the gases from the furnace to the uptake. A row of tubes B is arranged below and somewhat detached from the bank of tubes, the lower tubes being connected with the boiler circulation by expanding their ends into horizontal boxes C and D; these boxes being connected by short tubes E to the headers. Now, if all of the tubes B should discharge their circulatory water into a single chamber, the circulation of the boiler might

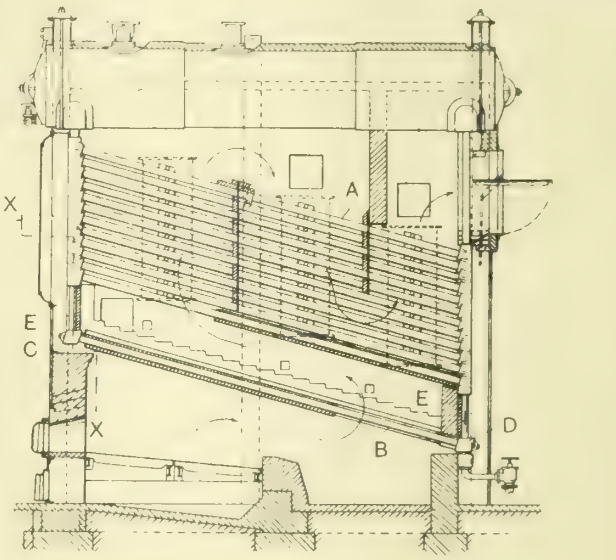


FIG. 1

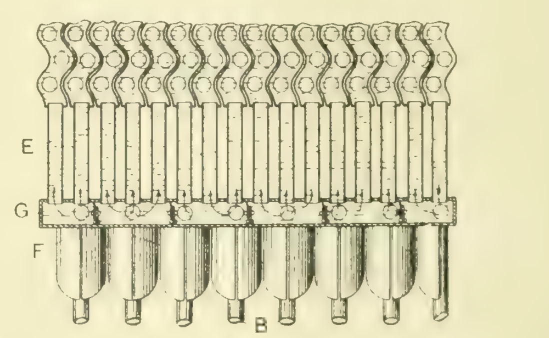


FIG. 2

IMPROVEMENTS IN WATER TUBE BOILERS.

be disturbed by greatly varying heat conditions on opposite sides of the furnace. In order to prevent such disturbance, diaphragms F are placed in either or both of the boxes C and D, dividing them into a number of separate chambers G thereby preventing the crossing over of the circulatory water from one end of the box or of each box to the other end of the same. The boxes are divided by any desired number of diaphragms, five diaphragms being shown, whereby the tubes of the bank are formed into groups of two and three tubes in width. One or more tubes B communicate with each chamber G, as shown in Fig. 2, and the diaphragms F may be so disposed as to provide one or more outlets from each of the chambers of the box C connected to the front header, the water in each chamber being compelled to take its exit through the tube or tubes leading into that particular compartment into which it is supplied. By the use of these diaphragms the circulation of the boiler is divided into vertical sections, that is to say, the circulation through any group of two or three of the vertical headers, as the case may be, together with their heating tubes will be independent of the circulation through the remaining tubes of the boiler.

USE OF WASTE HEAT OF OPEN-HEARTH FURNACES.

AN interesting paper by J. Schreiber devoted to the methods of utilising the heat of the waste gases from open-hearth furnaces appeared in recent issues of "Stahl and Eisen," and we are indebted for the following abstract to "The Iron Age." The author, who is superintendent of the Phœnix plant in Duisburg-Ruhrort, describes the installation there for raising steam with the waste gases, giving also the results obtained. References to the work of Mayer and Springorum show that from 29 to 32 per cent. of the heat developed in the open-hearth process is carried away by the waste gases. The theoretical temperature at which the waste gases should enter the chimney is given at 300° C., a temperature which is not reached in practice, because with active operation it is unavoidable that a considerable part of the hot gases burn while passing through the ports and checkers, or even after leaving the reversing apparatus. Even if it were possible that by some arrangement the temperature of the gas and air entering the hearth could be kept constant between reversal periods, the theoretical waste gas temperature is only lowered to 273° C., or about 10 per cent. less than 300° C.

As a matter of fact, the waste gas temperatures are considerably higher with most open-hearth furnaces. In general they may be given as from 600° to 700° C., but with active working they are often much higher. If lower figures are obtained the reason may not be better furnace efficiency, but greater radiation losses before the gases enter the checkers, or loose brickwork allowing the entrance of cold air. These temperatures hold good for the ordinary scrap process, and it is natural that higher ones should be obtained when liquid metal is used. Springorum gives 630° to 960° C. for the Hoesch process, but here the temperature of the producer gas was proportionately high, being 800° to 870° C. The use of cold gas, such as mixtures of coke oven and blastfurnace gas, should give lower figures. Simmersbach found an average of 565° C. when using a mixture of coke oven and blastfurnace gas, and 560° C. when using coke oven gas alone. A private communication gives results of 450° to 500° C. when using a mixture of producer, blastfurnace, and coke oven gas, and an average of 780° C. when using mixed producer and coke oven gas. This 30 per cent. of the heat developed which is carried away by the waste gases must not be considered as altogether lost, because it produces a considerable draught in the chimney which is necessary to carry on the operation.

Experiments were carried out by Herr Wibberenz from the beginning of October, 1911, to the end of February, 1912, with a 10-ton furnace at the plant of the Gelsenkirchener Guss Stahl und Eisenwerken, and 350 heats were made after the boilers were connected. Exact figures as to the amount of steam raised could not be obtained owing to the local conditions, but a comparison with the preceding year showed that 1.15 tons of steam were raised per ton of coal used in the producers. The furnace was slowed down somewhat owing to the long narrow gas conduit to the boilers and the coming together of the waste gases from the furnace and the neighbouring boilers, and as the necessary changes could not be made the boiler plant was disconnected. If a boiler plant were connected to a 30-ton furnace it would need a much larger chimney to give the necessary draught because there is the increased resistance of the boilers to be overcome, and also the gases will enter the chimney at a much lower temperature than before. Accordingly when in 19[illegible] the introduction of waste heat boilers was considered for the new Phœnix plant, it was resolved to experiment with the use of artificial draught on an old 20-ton furnace. It was decided to use the Schwabach patented method to produce the suction, and a boiler with 1,378 sq. ft. heating surface together with a Schwabach apparatus, was installed. The test was satisfactory to the extent that the operation of the furnace was not slowed down; on the contrary a speeding up was possible. The boiler, however, was too small, for the waste gases were only cooled down from 700° and 750° C. to 400° and 450° C. It was concluded to install a sufficiently large suction plant for the 30-ton furnaces in the new plant, and as the results were satisfactory the 50-ton furnaces were also equipped.

To carry out the Schwabach method a fan draws cold air from the atmosphere and blows it into the chimney-like suction apparatus, which takes the place of the ordinary chimney, and is provided with arrangements like tuyeres. The proper pressure is determined by experiment, and the strength of the suction exerted on the gases of combustion depends on the size of the fan, the revolutions per minute, and the area of the tuyeres. The latter can be regulated by means of a rising and falling double cone arrangement. The waste gases, after they have mixed with the air from the tuyeres, which produce the suction, are blown out through a short chimney which widens toward the top. It must be admitted that the combination of a boiler and suction plant with an open-hearth furnace may appear to bring about an undesirable and unsuitable complication. It should be remembered, however, that the gas producer and the whole furnace operation rest on the certainty of operation of boilers, motors, and fans, and that with good construction and suitable arrangement there should be no trouble. The plant must further be kept in very good condition, and above everything else looseness in the construction must be avoided.

Meanwhile the advantages are considerable and weighty. First comes the absolute independence in regard to the influence of weather on the draught; further, the possibility of bringing about good working with an old furnace in the flues and checkers of which deposits have formed. Next is the very satisfactory regulation of the draught, by means of which the furnace is under complete control; the complete elimination of chimney valves which always give trouble; and finally, but not the least [illegible], the possibility

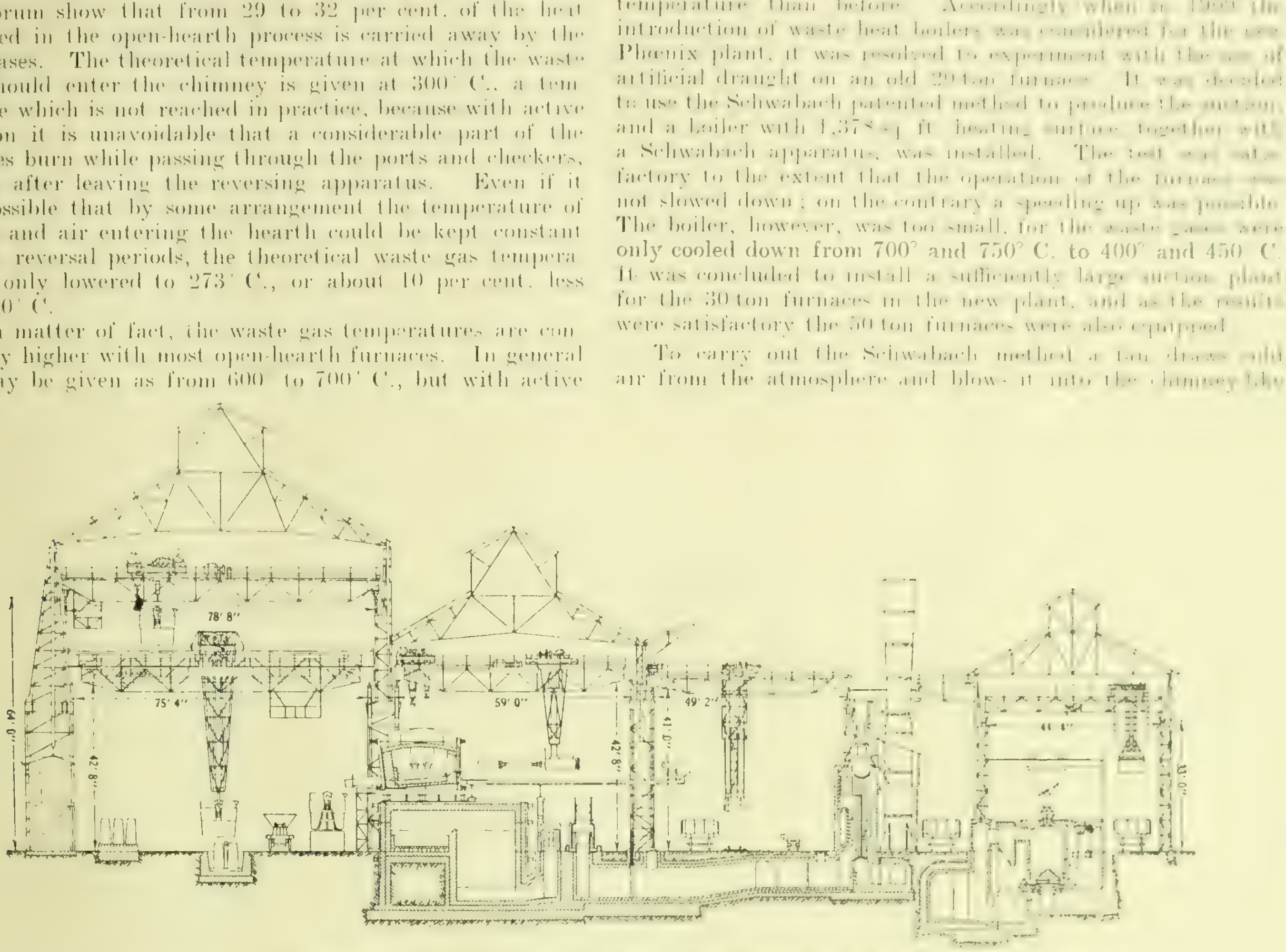


FIG. 1. CROSS SECTION OF OPEN-HEARTH PLANT EQUIPPED WITH WASTE HEAT BOILERS.

of using a certain amount of the waste heat without damaging the furnace operation.

The new open-hearth plant at Ruhrort has five furnaces —three of 50 tons capacity, one of 30 tons, and one that was originally 30 tons but has been increased to 40 tons. A general cross-section of the plant is shown in Fig. 1 and a more detailed drawing of the waste heat arrangement in Fig. 2. The waste gases are led from the reversing valve to the boilers through a conduit 49ft. 2in. long. Two boilers are provided for each furnace, those for the two smaller furnaces having 2,153 sq. ft. of heating surface and 538 sq. ft. overheating surface. Those for the 50-ton furnaces have 2,691 sq. ft. and 700 sq. ft. respectively. Two boilers are used, so that if one boiler is shut down for any reason the gases can still be used under the other, and some heat utilised. The conduit, therefore, forks in front of the boilers, and the separate channels can be closed by valves, if necessary, for relining. Fig. 2 also shows a conduit leading from the waste gas conduit around the boilers directly to the base of the suction apparatus. As a rule this is not used; but in case both the boilers are down the hot waste gases can be conducted through it. For this reason the steel chimney-like pipe, which is 56ft. or 69ft. high, is lined through with firebrick, although this would otherwise be unnecessary. The case of the breakdown of the motors or fans is also provided for, the necessary suction being then produced by a steam blast. In this way all possible troubles are taken care of. The steam produced is used in the gas producers, the excess being taken to the basic Bessemer mill and the rolling mills, and the steam is therefore only furnished at 120lbs. pressure, although the boilers can give 180lbs.

The boilers chosen were the Garbe patent because they fitted best into the available space. The volume of the waste gases and therefore the power required in the suction plant, apart from the temperature and the coal burned, depends on the excess of air present. The entrance of air through loose brickwork, &c., is therefore to be avoided as much as possible, and under certain conditions it may be advisable to replace the ordinary loose-fitting butterfly valves for the air with tightly-closing reversing arrangements such as are used for the gas. The entrance of air through the brickwork around the boilers cannot apparently be prevented even with the greatest care, it being brought about by the porosity of the brickwork. The results obtained are summarised in Table I.

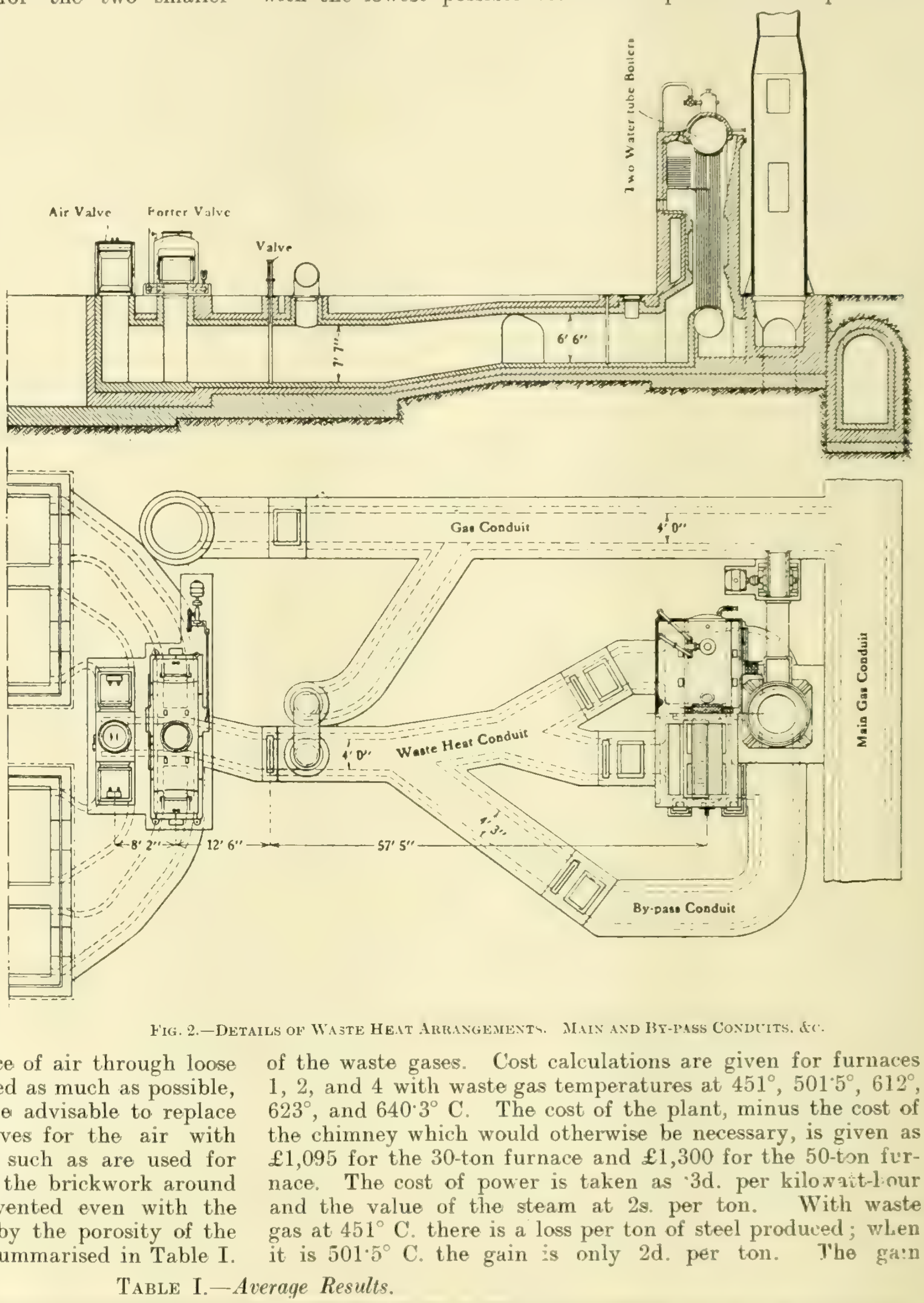


FIG. 2.—DETAILS OF WASTE HEAT ARRANGEMENTS. MAIN AND BY-PASS CONDUITS, &c.

40 per cent. of the heat in the waste gases is used, but that about 60 per cent. is still unfortunately lost with the present plant. In other words, the 30 per cent. loss of the heat developed in the furnace operation is reduced to about 18 per cent.

The next question is that of economy, and of course it must be remembered that the business of the open-hearth is not the raising of as much steam as possible, but is much more the production of the largest possible tonnage of steel with the lowest possible coal consumption and temperature of the waste gases. Cost calculations are given for furnaces 1, 2, and 4 with waste gas temperatures at 451°, 501·5°, 612°, 623°, and 640·3° C. The cost of the plant, minus the cost of the chimney which would otherwise be necessary, is given as £1,095 for the 30-ton furnace and £1,300 for the 50-ton furnace. The cost of power is taken as ·3d. per kilowatt-hour and the value of the steam at 2s. per ton. With waste gas at 451° C. there is a loss per ton of steel produced; when it is 501·5° C. the gain is only 2d. per ton. The gain

TABLE I.—*Average Results.*

Time.	Furnaces.	Size, tons.	Duration of Test, hr.	Entering Gases, Deg. C.	Gases in Chimney, Deg. C.	Steel Produced, Tons.	Coal Per Ton Steel. lb.	Normal Steel. Lb. per Sq. Ft. Heating Surface.	Lb. per Metric Ton Coal.	Lb. per Metric Ton Steel.	Remarks. Heats on Checkers.
Jan., 1912 ..	1	30	24	451·4	—	133·9	494	0·4513	1,555	348	After 176 heats
Feb., 1912 ..	1	30	24	501·5	—	136·7	483	0·7255	2,498	549	After 284 heats
Aug., 1912 ..	2	30	24	612·7	304·7	150·1	466	1·0189	3,289	498	After 503 heats
Sept., 1912 ..	1	40	24	623·1	318·8	176·4	472	1·3573	3,644	796	After 715 heats
Sept., 1912 ..	3	50	24	657·4	341·5	217·1	472	1·2800	3,564	765	After 397 heats
Aug., 1912 ..	4	50	24	707·6	352·4	199·51	516	1·4386	4,106	974	After 160 heats

Tables are given showing the steam test made during separate heats from furnaces 1, 3, and 4. These results are brought together in Table II., from which it is seen that about increases with rising temperature. With 612° C. it is 1·9d. per ton; with 623° C. it is 3·3d. per ton; and with 640·3° C. it is 4·2d. per ton. The basis taken is 250 working days per

year. These results put in another way show that the yearly excess over the capital invested in the plant is 11·5 per cent., 26 per cent., 54·3 per cent., and 66·9 per cent., respectively, increasing with the waste gas temperatures and the size of the furnaces.

By the use of economisers it is calculated that the waste gases can be cooled down 40° or 50° C. more, the amount of heat utilised being raised to 50 or 55 per cent. and the heat escaping by the chimney reduced to 45 or 50 per cent. The use of such economisers will scarcely increase the operating costs, because, although a little more resistance will be introduced, the cooling will reduce the volume of the gases to be moved, and the two will probably equalise each other. It must be remembered that this is only a first step in the utilisation of the waste heat, and that further tests and work must be done to improve the results and reduce the loss.

TABLE II.

Furnace.	Heat.	Temp. of Gases. Entering Boilers.	Temp. of Gases. Leaving Boilers.	Heat Taken up by Boilers.	Loss in Waste Gases Leaving Boilers.	Loss by Radiation, Conduction, &c.
		°C.	°C.	%	%	%
4	451	719	349	44·2	55·6	0·2
4	459	686	346	44·9	54·0	1·1
1	674	623	310	43·8	53·4	2·8
3	708	604	348	39·2	60·6	0·2

THE PREVENTION OF INDUSTRIAL ACCIDENTS.

IN a paper recently presented before the National Metal Trades Association, New York, Mr. W. H. Doolittle, safety inspector to the association, said the application of scientific principles to accident prevention had met with success. A comparison of available statistics indicated that time, energy, and thought expended in this way had been the means of greatly reducing both the cost and number of accidents. A reduction of 29 per cent. on a division of an immense railway system, of over 60 per cent. in the mills of some of the great steel companies, and of more than 73 per cent. in proportion to the number of operatives in a large industrial plant were results that must appeal to both humanitarians and financiers. In all of these instances the results were accomplished by systematic efforts.

The author enumerated some of the essentials of scientific accident prevention work, as follows: (*a*) The setting aside of time for the investigation of the subject of accident prevention. (*b*) Careful and continual inspection of workshops. (*c*) Investigation of the cause of each accident and the recording and tabulating of the same. (*d*) The study of the causes of accidents which occurred in like industries and under similar conditions elsewhere. (*e*) The installation and maintenance, wherever possible, of mechanical safeguards and safety appliances. (*f*) The education of the workman as to the dangers of his occupation and the best means of avoiding accidents in connection with his work. (*g*) Securing the co-operation of the workman in the efforts of the employer to promote safety and prevent accidents.

Accident prevention, he observed, could not be successfully accomplished without inspection. Inspections should be thorough in order that nothing dangerous might be overlooked. They should in all cases be made by competent and practical persons who had a technical and practical knowledge of dangerous places. Inspection should also be made by every person in the plant, particularly in the locality in which he was employed. Inspections should be frequent—conditions changed constantly. When an accident happened, the first thing to be done after caring for the injured person was to investigate the cause, in order to prevent its repetition. The author took issue with those persons who declared that "accidents just happened." Such a statement was not much more than an effort to evade responsibility. It was an unfounded and pernicious statement, tending to put a premium on carelessness and to promote accidents. Every accident was capable of analysis and in nearly every case the cause might be located. This should be done and a record kept for future guidance. Such statistics, carefully kept, were of great value.

Every man who had the safety of his employés at heart and every workman who desired industrial safety for himself and for his fellowmen would, he remarked, give attention to happenings outside of his own plant. Machines and methods were proved to be dangerous by observing their operation and the results in different localities. The larger the field covered the more valuable would be the data gathered. Circular saws, for instance, cut, kick, and kill in the same way in every part of the world. A serious accident might not have happened in a particular shop in all of its history, but this circumstance did not constitute an excuse for neglect. No plant, no industry, no locality was immune from accidents. The most successful safety engineers profited by the experience of others. There were many dangerous features of workshops that might be made comparatively safe by means of guards. It was important that set screws, gears, dead ends, and all other man-killing parts of machinery be covered, enclosed, or eliminated. All of this might be done without in the least cutting down the output of a factory—indeed it tended to add to the output by giving the workman a sense of security. It was not enough, however, that safety devices be installed. They must be maintained. Someone must see to it that safeguards were kept both in order and in place. If for the exceptional job a guard must be removed, it should be immediately replaced.

No workman should ever enter a dangerous occupation without being made to give strict attention to the dangers connected with it. He should be made to do this not only for his own protection, but also for the sake of his fellow workmen who might be injured as a result of his lack of precaution. Every employer was morally responsible for the safety of his employés just so far as he, by the exercise of his authority, might prevent their being injured. Nor was it entirely an ethical question. It was not profitable to the employer for his workmen to be injured. Aside from the humanitarian aspect of the question, in a general way physical injuries to the workman meant financial loss to the employer. Therefore, for all of these reasons, ethical, humane, and economic, the employer should instruct and warn the workman of danger. No task should ever be imposed which in its performance would endanger the life or limb of the workman. Workmen might be warned by word of mouth, by the judicious use of signs distributed about the plant, and by literature. Warnings must be persisted in, otherwise they were of no avail. Many workmen were naturally careless, many others were purposely negligent, others viewed with suspicion efforts that had the appearance of altruism. Every possible effort should be made to secure the co-operation of the workmen in the safety movement, for progress in accident prevention beyond a certain point was utterly impossible, if the opposition or indifference of the workmen to this important work was not overcome.

In conclusion, the author affirmed that luck as a factor in accidents was always more or less under the control of man; that both good and bad luck were produced by the operation of natural forces; that these forces moved according to well-defined rules, or laws; and that men were lucky or unlucky just in proportion to their understanding of these laws and their disposition and ability to live and act in harmony with them.

Fatal Steam Pipe Explosion.—The inquest on Richard John Court, third engineer, and George Neville, stoker, killed in an explosion on the steamer "Millwall," of Cardiff, was held at Fleetwood on the 16th ult. William Newton Beeny, the chief engineer, who managed to escape by getting into the funnel, said that the explosion was due to the main steam pipe of the starboard boiler blowing out of the stuffing-box. He had previously received instructions to open out the machinery with a view to a survey in anticipation of the sale of the vessel. This was done, and the following Wednesday he got instructions to close up. He allocated the work among his staff, and one of Court's duties was to replace certain clamps on the main steam pipe. Inadvertently Court omitted to do so, and immediately full steam was on it blew the pipe out of the boiler. He (Mr. Beeny) took personal responsibility, but the pressure of work of getting ready for sea made it impossible for him to see personally to all details. The jury returned a verdict of accidental death.

PIPING AND SEGREGATION OF STEEL INGOTS.*

DR. P. H. DUDLEY.

The piping and segregation of ingots of steel is a comprehensive subject, and must be studied in reference to the different grades of soft, medium, and hard steel, rather than to discuss it in a general manner, as though applicable to all grades. Rail steel, however, will receive the most consideration in this paper.

Bessemer steel of from 0·10 to 0·15 per cent. of carbon, for splice bars, spikes, and tie plates, rises in setting, and is cast in bottle mouthed moulds, which must be capped to prevent an overflow from the top. This grade of steel rises in the moulds and makes a longer ingot than the volume of molten steel when first teemed. The ingots, which are allowed to cool and then cut open show, particularly in the upper part, large ecluded blow holes, and when they are not oxidised or contain foreign matter, weld more or less completely when the steel is rolled or forged above 1,100 C., and it is in this way that the blow holes are closed in the low-carbon steels.

Boiler-plate and firebox steel often contain more or less minute laminations, which are the remains of small blow holes forming after the setting metal has reached a pasty condition. The blow holes in the low-carbon steels have not been prevented by using deoxidisers, though the ingots are slightly improved so far as the soundness of the steel is concerned. This grade of steel also rises in the moulds in setting.

Rail Steel.

Ingots of rail steel containing from 0·50 to 0·75 per cent. of carbon are of an entirely different character when they are sufficiently deoxidised to form comparatively pure steel, as a well-defined shrinkage cavity forms, incident to the cooling and setting on the bottom from the stools and sides of the moulds, and then caps over on top, enclosing a larger volume of hot metal than would be the case when cold.

This important fact should be remembered in discussing rail steel, for the greater the degree of its deoxidation, the larger will be the difference between the enclosed volume of hot fluid metal in the mould and the cooler resulting set metal, and the still proportionately lesser volume, should the ingot be allowed to become cold before equalising the heat and rolling. We must deal with three conditions or stages of the steel: (1) The greater volume of hot molten metal; (2) the lesser volume of hot metal; (3) the least volume of cold metal in the dimensions of the rail sections.

The exterior blow holes in the outside walls of the ingots can be prevented from forming by sufficient deoxidisers, as silicon, ferro-titanium, or their combination, and aluminium. The latter has been extensively used, but all of its oxidation products do not always escape from the metal, and it should not be used when the steel is to be subjected to the present heavy wheel loads. The silicon content for rail steel now ranges from 0·10 to 0·20 per cent., to make it sound and prevent small blow holes from forming in the setting metal. When sufficient deoxidisers are used to purify efficiently the steel, then, as must be expected, a small cavity starts to form in the top under the cap of the ingot in the setting steel, and its development should be retarded by stripping the ingot and promptly charging into the reheating furnace.

Rail ingots are no longer allowed to become cold before being charged into the reheating furnaces for blooming. The size and length of the ingots must be taken into consideration, for in those ingots of which the length is from four to five times the width of the base, the steel will set on the interior walls long before their vertical shrinkage of hot to cold metal has occurred, and this increased length will add proportionately to the volume of the interior piping or shrinkage cavity.

It was customary a few years ago to teem ingots which were only 18in. by 20in. or 19in. square, and roll four lengths of 100lbs. 33ft. rails. The height compared with the base was so great, that before any shrinkage occurred in the vertical hot ingot walls, the interior shrinkage cavities developed so large, they could not be prevented entirely from forming, even by prompt charging of the ingots after stripping into the reheating furnaces to equalise the heat for rolling.

The heat of the metal is abstracted by the stools and sides of the moulds, and the ingot walls set; then the top caps over quickly before shrinkage in the length of the ingot occurs, and as the hot volume become reduced by the setting exterior walls, the interior shrinkage develops a large cavity under its top cap when the ingot is allowed to become cold. The sides of the contours of the shrinkage cavities in well deoxidised steel are parabolic in form, and of proportionately greater volume and depth in the long type of ingots than in those which are short and stubby, but of larger volume and base.

The 33ft. 100lbs. rails rolled from four rail length ingots of the long type developed in the track a great many split heads and some true pipes, the product from two or three mills being quite pronounced in this respect. Rails which were rolled during August and September, one purchaser removed in less than six years' service, more than 10 per cent. of the quantity for split heads. The trackmen would report these rails as piped, for the segregated metal in the head would crack under the fillet and admit the air, which would soon discolour the interior surface, and these are considered

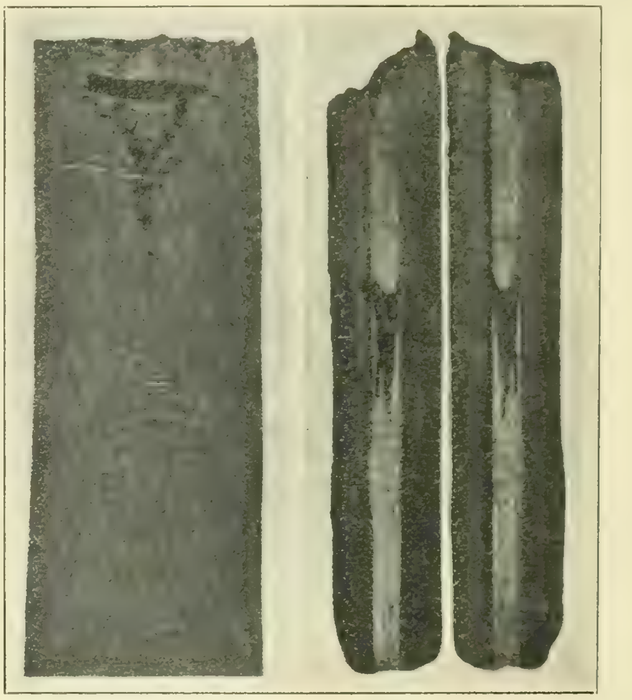


Fig. 1. Fig. 2.
Cavities in Ingot and in Crop from Bloom of Companion Ingot

as piped rails. There was in some instances a true pipe or shrinkage cavity when rolled, which extended into the centre of the web, and well up into the head. The trackmen, however, were not able to distinguish between the true piped rails and split heads, and it was some time before the latter were attributed to segregation and slag enclosures, which, when recognised, were nearly prevented in subsequent manufacture of rails.

When the mills began to make 33ft. rails and teemed them in the same ingot moulds which had been used for 30ft. rails, and then rolled them in four 33ft. lengths for 100lbs. rails, a great many ingots were not stripped, weighed, and charged into the reheating furnaces with sufficient promptness to prevent a number of piped rails, as the requisite mill practice to check them was not then comprehended under the changed manufacturing conditions. The segregation was also large, and in 1908, for the New York Central Lines, I confined the rolling of Bessemer and open-hearth rails in the United States mills to three 33ft. rail-length ingots for those of about 19in. square upon the base. It was also stated in the specifications for the New York Central Lines that short, stubby ingots of from 2·5 to three times the length of the width of the base were required for rails. Ingots of about 8,200lbs. weight, teemed in moulds 20in. by 24in., have been exten-

* Abstract of paper read before the New York Meeting of the American Institute of Mining Engineers.

sively made for six lengths of 33ft. 100lbs. rails, and, in good mill practice, with practically complete elimination of piped rails. The blooms, however, are cut, and only rolled in three rail lengths at a time. Ingots, 25in. by 30in., of about 12,000lbs. weight, have been used for eight 33ft. basic open hearth 100lbs. rails where the ordinary rail mill equipment had not been installed. The ingots were bloomed and then shipped to a rail mill to be reheated and rolled, and but a few piped rails were found during manufacture. The rails in the track fulfil the requirements of safety and severe service. The large mass of metal in the short ingots does not quickly cool, and from the teeming of from 60 to 80 ton melts, the ingots would be charged into the reheating furnaces in 1 hr. 30 min., and before all the interior metal had set, with but a trace of a shrinkage cavity started. The distance run by the ingots on their cars from the open hearth department to the strippers and then to the reheating furnaces, aids to consolidate the hot metal in the centre of the moving ingots.

Cutting Cold Ingots to see the Volume of the Shrinkage Cavity.

Ingots have been teemed and stripped in the ordinary manner, then taken to the reheating furnace, and, when ready for rolling, taken out, allowed to cool, and when cut, as would be expected, have shown a shrinkage cavity. The blooms from the companion ingots, when promptly charged into the reheating furnaces and rolled, as in proper mill practice, would show only a small trace of the cavity compared with that in the cold cut ingot. I do not know where similar comparisons will be found outside of my own work of cutting ingots which have been allowed to cool, and also cutting blooms of companion ingots as rolled under the best practice of to-day. The necessary mill practice to secure pipeless rails must be understood, and the time limit from teeming, stripping, weighing, and charging into the reheating furnaces, involves definite relations to the mass of metal, its chemical composition, the length of the ingots and size.

I call attention to the fact in the specifications for the New York Central Lines to the mill practice, that as soon as the ingots are stripped they should be charged into the reheating furnaces, to prevent the setting steel to cool from its molten temperature to that of cold metal, and thus avoid the formation of the full shrinkage cavities in the ingots. It has been shown by the cutting of a large number of blooms that it is possible to prevent a shrinkage cavity from forming of not more than from $\frac{1}{20}$ to $\frac{1}{30}$ of the size in the top of the hot ingot by this method of good mill practice, of what would be formed by permitting the ingot to become completely cold before it was put into the heating furnace for rolling.

Bloom crops which have been split from companion ingots show only a slight indication of the shrinkage cavity, which is removed by the discard. The mill practice of promptly charging ingots, after stripping and weighing, into the reheating furnaces, I have followed for many years, and but a few piped rails required rejection during the manufacture, testing, and inspection. The latter commenced in the converting department, and ran through the mill to the finishing and shipping department. There are only 25 piped rails known to have been found subsequently in service in the track in 65lbs., 70lbs., 75lbs. 80lbs. 95lbs., and 100lbs. sections out of about 1,100,000 30ft. rails, of which the length of the ingot was not over, but under, three times the width of the base. The ingots were all stripped by hand in the teeming pit and charged into horizontal reheating furnaces, a mill practice long since abandoned. Many of those 0·06 per cent. of phosphorus and from 0·60 to 0·65 per cent. of carbon rails are still in freight and branch line service. Some split heads have developed in these rails, due to segregation and the heavy service to which they have been subjected.

I was at the mills co-operating in the manufacture and inspection of the rails, and commenced in 1893 to indicate their position in the ingots, and stamped on the web of the top, middle, and lower rails the letters A, B, C, respectively. This was for the purpose of studying their subsequent wear and behaviour in the track, which has been so instructive that the practice of designating the rails by letter for identification in the track has become general for the United States.

The "A" rails contain a larger percentage of oxides, which rose in the steel before completely setting in the ingots, and wore faster than the "B" or "C" rails under the same traffic. The breakages, however, have been slight in either the "A," "B," or "C" rails after their many years of service. The ingots were teemed with deep sinkers in the moulds of about 2·5in. radius, and in the "A" rails, particularly, oxides and slag were entrained in the segregate by the columnar structure of the setting steel. The gauge-side corner of the "A" rails would show indications of breaking down and spreading to a greater extent under the heavy traffic than the "B" or "C" rails. It was possible, after the rails were in the track eight or 10 years, to identify by casual inspection the "A" rails from the "B" or "C" rails, by the more frequent sprawling on the gauge-side corner of the head.

The "A" rails in the 80lbs. sections which were in the freight track of the New York Central and Hudson River R.R. in places of heavy traffic lost the metal faster than the "B" or "C" rails and, in a few places, were removed and laid by themselves to ensure equal heights of the worn surfaces. The same characteristic of wear was noticed on the 100lbs. rails, and also upon the 95lbs. rails of the Boston and Albany R.R., though the "A" rails were never separated on account of the increased wear.

The comparatively few piped rails indicated that attention to the mill practice of charging the ingots promptly into the reheating furnaces, as already described, did contribute to the soundness of the rails. Therefore, similar good mill practice would be beneficial for the larger and heavier ingots of recent manufacture, and the exceptional freedom from breakages of rails made from them, in service during the past winter, has again confirmed the value of such mill practice and essential study for basic open hearth steel.

We must first provide the hot molten metal with a chemical composition which will produce sound ingots and definite physical properties in the finished product. Our first effort is to secure a well deoxidised steel, and by proper mill practice make sound ingots. This method has given excellent results in the past, and by the necessary study and attention of the consumers and manufacturers, it is possible to obtain greater perfection. It is important to understand and observe the principles which contribute to better practice, and in this the consumer must materially aid the manufacturer by advising him of the type of failures which occur in rails under service. It is requisite for more than one person to know the principles of good mill practice, that all of the general conditions of manufacture may be followed to produce the desired results.

There are several methods by which a refractory brick is placed upon the top of the ingot mould, and when filled with molten steel is kept hot by gas jets or charcoal to cause the hot fluid metal to fill up the shrinkage cavity formed by the setting steel in the ingot. Such methods have not been used for rail steel to any extent in America, though many thousand tons have been made from ingots in which coke dust was thrown on the top of the molten steel in the mould, and it fed the shrinking volume of setting steel. Granulated slag has also been used. When refractory bricks are used, more deoxidisers are added to the steel for the purpose of ensuring the elimination of all blow holes and increase the tendency of the steel to shrink and permit the molten metal to feed the lessening volume. It was a common practice a few years ago in teeming ingots to add 2oz. or 3oz. of aluminium per ton in the moulds to reduce the oxides in the steel.

Benjamin Talbot, of England, at the present time, proposes to cast molten metal in large ingots, 25in. square or 20in. by 24in. on the base, and poured to a depth of 60in. or more, and after the ingots are teemed, stripped, and put into the reheating furnaces for about 30 minutes, and while the centre is still molten, to cog them down to 18in. square. Then the bloom with the fluid centre is put into the reheating furnace to set and the heat allowed to equalise before it is rolled into the final section. The shrinkage cavities are said to be completely closed, and ingots which have been made in England show on the exterior a chemical composition of about what the ordinary ladle tests show. Then there is a layer of higher carbon content, with a softer centre than the out

side. He uses a large percentage of aluminium or silicon or ferro-titanium to make his steel sound, and then, by his method of precogging, eliminates the cavity and produces an ingot in which the metalloids are not uniformly distributed. Several ingots have been made, a few rolled into rails and tested under the drop in England, which were said to show good results. This, in a measure, would be almost the reversal of segregated rails, in which we find the different layers of metal fail from the upper portion of the ingots under our heavy wheel loads.

Sir Robert Hadfield recommends his patented process by which he places a refractory enclosure on the top of the mould and fills it with molten metal, filling up the ingot, and then by the use of a layer of slag, 0·5in. or more in thickness, on the molten metal, he puts charcoal and fires it by a blast of air, which prevents setting of the top metal, and feeds the shrinking volume of that beneath. He states that his process enables him to produce ingots of which 92 per cent. of the weight is available for use.

It is important to call attention to the fact that either by the methods of Mr. Talbot or of Sir Robert Hadfield, they consider it necessary to use a larger percentage of deoxidisers than is customary in the bath, to produce what they term "piping steel." This indicates that their ordinary open-hearth product, as made, is not of itself sufficient to reduce the oxides in the steel as low as they consider essential to eliminate the exterior blow holes and make the ingots set solid, except what would be the natural shrinkage cavity, which their special methods are intended to prevent or close by treatment.

The views of Mr. Talbot and Sir Robert Hadfield are old, as to the desirability of completely eliminating the blow holes and causing the steel to set sound at the risk of producing a shrinkage cavity, which must be checked from full development, and have been held and practised by me for the past 30 years in the production of ingots for steel rails. The deoxidisers, aside from the manganese, should be sufficient to cause the steel to set sound, as is shown in the metal of the cut ingot (Fig. 1) without blow holes nearly to the extreme top of the cold ingot.

The principles of making good ingots for all high-carbon steels are understood by metallurgists and manufacturers as well in America as abroad. It is now recognised that the bath must be efficiently purified to secure sound ingots of the requisite physical properties and ductility in the fabricated articles or rolled rails. The important fact, however, is not understood by all railway engineers, that the effort to make piping steel is for the purpose of securing sound ingots. The suggestions of Mr. Talbot and Sir Robert Hadfield, to use a large percentage of aluminium in the ingots to reduce more completely the oxides, I do not consider advisable, from the difficulties already experienced with aluminium so used in rail steel for our heavy wheel loads. It would be better to use silicon or a combination of silicon and ferro-titanium to secure the desired results. We do not use as high percentages of silicon in steel as is employed abroad, except for tyres.

It is now found for our heavy wheel loads and severe service in the low temperatures of several of the important trunk lines, that the high silicon tyres break more frequently than those in which the content is lower. The suggestion to use from 0·3 to 0·4 per cent. of silicon in rail steel, without modification of the other chemical constituents, would involve the risk of many rails breaking from the slipping of the drivers upon the rail heads. We must proceed with proper caution in introducing deoxidisers which remain, or their oxidation products are liable so to do, in the bath of steel. Ferro-titanium, while more expensive than either aluminium or silicon, also acts as a flux, and can be used without danger of leaving its oxidation products in the well-made bath of steel. The impression prevails that to produce a greater soundness in steel by the use of the ferro-titanium as a deoxidiser is detrimental rather than beneficial, from the increased tendency to pipe the ingots. It is the proper use of subsidiary deoxidisers and their attending conditions which must be understood to secure sounder steel with, rather than without them.

Segregation of Basic Open-hearth Steel Ingots.—The segregation of Bessemer ingots has been studied extensively, but the basic open-hearth ingots for steel rails and wheels have not received requisite attention. I have studied their segregation in several ingots, but do not find it as great in well-purified steel as might be expected from Bessemer, which contains two or more times the impurities of phosphorus and sulphur. Well-melted, purified basic open-hearth steel sets quietly and the segregation becomes less in degree.

The Illinois Steel Company, at Gary, when rolling rails for the New York Central Lines, in 1912, at my request, took one ingot weighing 8,100lbs. from melt No. 54,428, and charged it into the reheating furnace as in ordinary mill practice; then, in about 2·5 hours, when in condition to roll, drew and set it outside the furnace to cool. The ingot was 20in. by 24in. on the base, and poured 73in. long. The shrinkage cavity shown in the cold-cut ingot, Fig. 1, is fully developed from hot to cold steel, and is more than 20 times larger than in the bloom-crop of the rolled companion ingot as charged in the usual mill practice. Charging 10 or 15 minutes earlier, the ingot would have prevented even as large a shrinkage cavity as found, in the bloom-crop, though it shows that 1·4 per cent. of sound metal was cut off in the usual discard and 0·75in. in depth was planed from the centre of the bloom and the small cavity was entirely removed.

The crop from the 8in. by 8in. bloom, 46in. long, from the companion ingot was split to examine the shrinkage cavities and segregation (see Fig. 2). The ingot when cool was split and planed, and five vertical rows of holes were drilled in one-half of the ingot, which were marked respectively A, B, C, D, and E. The distance between the vertical rows A and B was 2·25in., and for the other rows 3in. The transverse rows, Nos. 1 to 9, inclusive, were 3·75in. apart, but between Nos. 10 to 15, inclusive, the spacing was 7·5in. Drillings were taken from 64 holes of the ingot, and chemical analyses made for the carbon, manganese, phosphorus, sulphur, and silicon.

The crop of the companion bloom weighed 759lbs., representing 9·4 per cent. of the ingot, and was split and drillings taken from three vertical rows of holes. This made 73 holes from which complete analyses were made. The chemical composition by the ladle-test was: C, 0·71; Mn, 0·83; P, 0·025; S, 0·038; Si, 0·18. The vertical row of holes near the exterior of the ingot showed that the carbon ranged from 0·67 to 0·69. The carbon for the 15 holes of the next vertical row showed a slightly lesser content, while the next row showed a higher content than the ladle-analysis from the third to the tenth transverse row.

The segregation of the carbon was not as large as would be expected from the size of the ingot, the top indicating that the steel set quiet under the silicon content of 0·18 in the ladle, and that possibly one or two points were subsequently absorbed by the further deoxidisation of the steel in the mould before setting.

The average carbon from the drillings of the companion bloom (Fig. 2) was 0·67, while before cooling from the ladle test it seemed to be 0·71, a small practical variation, though it should receive consideration in an investigation of the causes of the segregation.

Metallic titanium to the amount of 0·1 per cent. in the steel would have reduced the segregation of the carbon to some extent, though with a tendency to increase the pipe, and to obviate the latter it would have been necessary to handle the ingot more promptly from the teeming, stripping, and charging into the reheating furnace. It was found that the manganese was nearly uniformly distributed and the phosphorus segregation was unusually small. There was some sulphur segregation, and nearly all the tests showed slightly higher percentages than the ladle analysis. The silicon in the ingot and bloom was nearly uniform, and in not a single instance did it exceed the amount shown by the ladle analysis.

CONCLUSIONS FOR THE MANUFACTURE OF THE PRESENT BASIC OPEN-HEARTH RAILS.

1. The chemical composition should provide for sound steel of ample physical properties of tenacity and toughness rather than hardness combined with brittleness.

2. The impurities, phosphorus and sulphur, should be of minor content, so that the bath of metal can be purified to produce the large percentage of toughness and ductility due to the specified chemical composition.

3. The ingot should have such relations of area of base compared with the height and weight that, under good mill practice and suitable deoxidisers, it can be made with controlled segregation, and only a trace of a shrinkage cavity in the top; then, when bloomed under its equalised initial heat, it is rendered pipeless by the usual 8 to 10 per cent. discard.

4. Aluminium can be replaced and silicon partly, as deoxidisers, with advantage by the use of ferro titanium to purify, solidify, and check segregation in rail, tyre, and axle steels, and also some of the lower grades of carbon steels where great purity is desired.

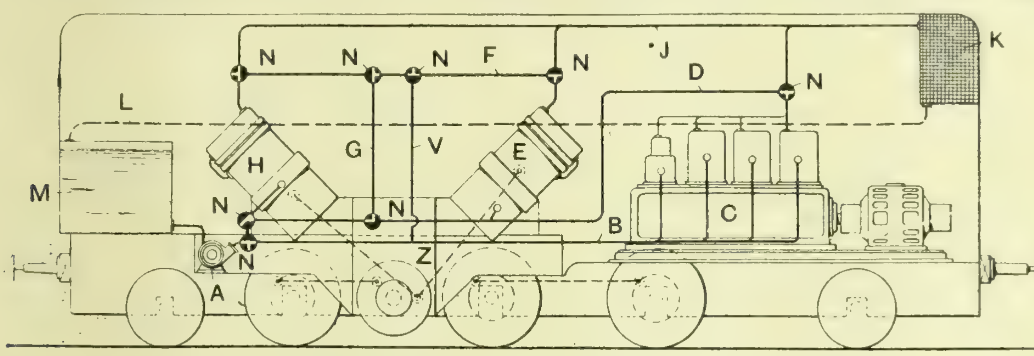
5. The ductility and elongation tests to date furnish the best and only prompt means of determining the degree of purification of the steel per melt as it is made, by indicating the physical properties secured before another melt is tapped from the same furnace, and are of decided advantage to the manufacturer as well as to the consumer. These tests are so advanced that they must be applied with knowledge and understanding for proper results, and not made mechanically, for specified records.

6. Every process or step of the entire manufacture of the steel, rolling and finishing of the rails, must contribute its part to secure the highest quality of the product incident to the chemical composition.

7. Specifications should be drawn to indicate some of the major necessities of the consumer, and the tests and inspection conducted in a spirit to aid and invite the co-operation of the manufacturers to meet the progressive requirements in rail steel.

COOLING INTERNAL COMBUSTION ENGINES.

A METHOD of cooling internal-combustion engines in cases where two or more engines or groups of engines are provided on a vehicle or ship has been designed and patented by Messrs. Sulzer Bros. of Winterthur. In the accompanying illustration the method is shown applied to a locomotive in which a driving engine Z is provided and an auxiliary engine C. The cylinders E and H of the main engine drive the wheels direct and the auxiliary engine C is primarily employed for producing compressed air for the brakes, for injecting the fuel, for circulating water and supplying electric power and light. The main supply of cooling medium is stored in the tank M and pumps A serve to circulate this liquid through the cooling system. Connected to the tank M is the supply pipe which leads to the individual cylinders H and E of the main engine and to the cylinders of the auxiliary engine C. The pipes for the cooling medium are so constructed that it either flows into the jacket of one cylinder only or into the jackets of one engine or, on the other hand, all the cooling liquid is distributed among the various cooling jackets of the several engines. By suitably connecting or setting the valves provided in the pipes the cooling medium may be supplied thereto direct from the tank M. The discharge pipes are arranged in a manner corresponding to the supply pipes and in their case also any desired connection can be obtained by means of the valves which are provided for the purpose.



ARRANGEMENT FOR COOLING INTERNAL-COMBUSTION ENGINES ON LOCOMOTIVES.

A special arrangement is provided which enables the discharge pipes for the cooling medium of one or more engines to be connected to the supply pipes of other engines or of their cylinders, cylinder covers, pistons, &c., and further enables the cooling medium to enter the main discharge pipe only after having passed through all these cooling jackets. The valves for effecting the different connections are diagrammatically illustrated in the accompanying drawing. All the cooling medium first flows from the pump A direct through the pipe B to the auxiliary engine C. Thence the cooling medium which has thus become heated passes through the pipe D to the cylinder E of the main engine and then through pipes F and G into the jacket surrounding the cylinder H on the main engine from which it flows through the pipe J into the radiator K mounted on the front wall of the locomotive. The cooling medium is cooled in the radiator K and returns through the pipe L back to the storage tank M from which the pump A again circulates it in the manner described. In order to set the different connections, valves N are provided at the various junctions or elbows, and further between the discharge pipe for the cooling medium of one engine or cylinder and the supply pipe for another engine is arranged a connecting pipe through which the waste water from such engine can be supplied to the other.

CRUDE-OIL ENGINES.

THE subject of "Crude-oil Engines" was dealt with by Mr. W. A. Tookey in a paper recently read before the Junior Institution of Engineers. The output from oil engine cylinders, he said, was the practical one due to the limitation imposed by the tendency of the mixture to preignite. As long as the temperature of the mixture could be controlled with consecutive impulse cycles, so that at the point of maximum compression more heat could be added in sufficient amount to start combustion—either by absorption of heat from the ignition tube, externally or internally heated by non-water-cooled vaporiser walls, or electric spark—so the engine could be relied upon to work satisfactorily, although with less heat efficiency than gas engines of equal output. But if such control of temperature during compression could not be ensured, owing to various causes which were now well understood, spontaneous combustion would take place and would result in preignition and, sooner or later, in the stopping of the engine.

Temperature control of the nature referred to was most easily obtained by means of water injection. The thermal storage capacity of metal and of water made it impossible to gain quick control by varying the amount of heat abstracted from the cylinder walls through increased circulation of water. Injection of water into the charge went at once to the seat of the trouble and reduced the skin temperature of the internal walls. In this way not only could preignition be stopped, but the rapidity of combustion due to rich mixture could be checked. The gases could be made to yield their heat less violently, so that not only could more power be obtained per impulse, through the use of richer mixtures, but the impulses themselves were of a nature which enabled more of the energy of the gas to be applied to the crank shaft. Even so, however, the performance of such engines was rarely better than 0·75lb. per brake horse-power hour at full load.

The bulk of residual or heavy oils available up to a year or so ago at low prices, but now unreasonably expensive, brought about a demand for engines capable of using them, and therefore from the kerosene engine had been evolved the crude-oil or semi-Diesel engine, in which the main difference was the injection of the fuel at or about the moment of maximum compression pressure, instead of during the suction stroke. This had greatly minimised the risk of preignitions, and had allowed the use of higher compression temperatures, with the result that heavier oils could be burnt effectively. The compression pressure varied in the engines of different makers from 150lbs. to 280lbs. per square inch, but the difference in these pressures apparently failed to affect the efficiency obtained, for the performance of both had been proved to be at the rate of 0·45lb. per brake horse-power hour at full load.

There was still risk of preignition at heavier loads when high mean pressures were demanded, and consequently richer mixtures were introduced. This was readily controllable by water injection. The capacity for heat storage of the hot bulb, which was a feature of the semi-Diesel type of engine, was a very important factor towards success, as was also the direction, pressure, and atomisation of the injected fuel.

A LARGE ELECTRIC POWER PLANT.*

THE NORTH-WEST STATION OF THE COMMONWEALTH EDISON COMPANY.

W. L. ABBOTT.

IN the days of direct current generating and distributing from central stations, when the fixed charges on the underground network were relatively greater than now, and the cost of underground copper was proportional to the square of the distance to which current was transmitted, a location as near as possible to the centre of gravity of the load was the prime consideration in selecting a power-house site. Naturally, in such cases land values were so high that it was found expedient to crowd the equipment into the smallest space possible, resulting in a congested station with high operating labour cost, running non-condensing and supplied with coal by wagon. With the development of alternating-current generation and transmission at high voltages, the use of rotary converters and frequency changers, and with enormous increases in the size of generating units and in the amount of power supplied, other operating costs decreased relatively to such an extent that the cost of fuel far exceeded them all combined. Therefore, the dominant factors now in determining the selection of a power site are the ones involving the economical handling and utilisation of coal. Let us consider these factors and their effect on the problem.

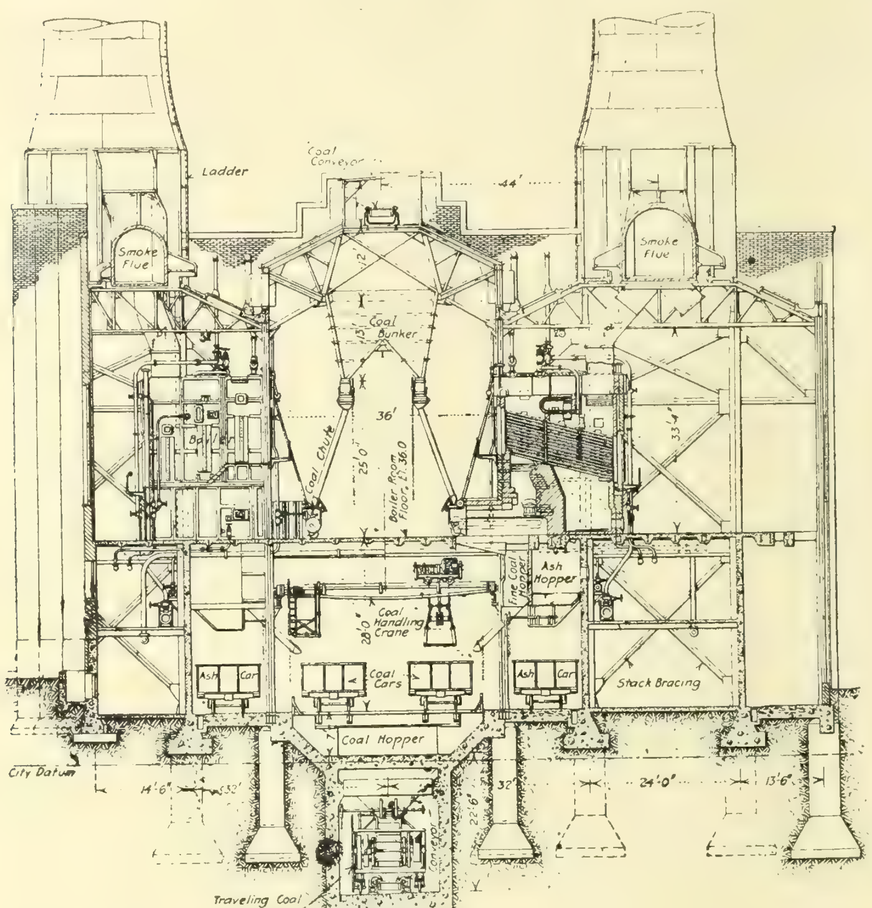


FIG. 1.—CROSS SECTION OF BOILER-HOUSE; NORTH-WEST POWER STATION OF THE COMMONWEALTH EDISON COMPANY, CHICAGO.

As the cost of fuel greatly exceeds all other operating costs combined, and as the consumption of fuel when running condensing and non-condensing, respectively, is in the ratio of 2 to 3, it appears that unless the coal consumption is to be increased 50 per cent. the power-house must be accessible to an abundant supply of condensing water. Desirable power-house sites are hard to find, so when a satisfactory location is found it is advisable to provide for a good-sized installation, and one which will take care of all increases in the load for a considerable period of time—say five years. At the time the North-west Station was to have been started (winter of 1911-12) the maximum load on the company's system was about 200,000 kw., and the indications were that for a number of years in the future the increase would average at the rate of 15 per cent. per year, which rate of increase applied to the load of 200,000 kw. indicated that the net increase of load during the following five-year period would amount to about 220,000 kw. Accordingly acreage sufficient to accommodate two power-houses of 120,000 kw. each was sought. It was not the intention to install this amount of power all at one time, nor even during the five years mentioned, as our existing power-houses could still be added to and other new power-houses might be commenced; but it was considered that a site which might be built up at will and eventually accommodate 240,000 kw. would not be at all too large.

What acreage then is required to accommodate a 240,000 kw. power house? Experience has shown that such a power-house supplying a diversified metropolitan load will at some seasons of the year run at a load factor of 50 per cent. of the installed capacity. For a 240,000 kw. installation this will require a daily coal supply of something over 4,000 tons, or about 100 carloads. To make a moderate allowance for the uncertainties of freight traffic over a distance of 200 miles, provision should be made for storing on the property at least three days' supply of loaded and one day's output of empty cars, amounting altogether to 400 cars, which will require four miles of storage tracks. The power-house, storage tracks, storage pile, and switch tracks will require about 50 acres of ground, but after allowing for convenient spacing, it will be found that the total space required for such a plant and all that goes with it is not less than 75 acres, the greater part of which is for receiving, storing, and handling coal. The site acquired for the new station is located near the Chicago river, between Roscoe and Addison Streets.

An aggregate of 240,000 kw., or 350,000 h.p., in one building creates possibilities for an interruption to the entire supply. It was therefore deemed prudent to divide this capacity between two separate power-houses of equal size, to which plan the power-house site is well adapted. The two power-houses are symmetrically arranged on either side of a central east and west axis. Each has its system of railroad tracks, and each has a large coal storage field spanned by a gantry crane 265ft. long. Water for condensing is drawn from the Chicago river through a double-deck tunnel, the upper conduit being used for the outflow, which is discharged into the river at a point several hundred feet down stream from the intake.

The North-west Station consists essentially of a turbine room 70ft. wide and 290ft. long, on one side of which is the boiler-house, in which the boilers are arranged in rows of ten, one row opposite each turbine. Each of the two North-west Stations is designed for six turbines and 60 boilers. On the side of the turbine room opposite the boiler room are the transformer house and the switch house, in separate though connected buildings. About two-thirds of the first station building group has been completed, although only one-third of the equipment has been installed.

Cars containing coal, when delivered at the station, are run on to tracks over the receiving hoppers under the boiler room (see Fig. 1). There the coal is dumped into the first receiving hoppers and from there it passes through the coal

* Abstract of paper presented before the electrical section, Western Society of Engineers, December 23rd, 1912.

crusher and into the conveyor, which elevates it to the second receiving hopper above the firing floor in the boiler room, from which second hopper it is drawn by gravity, as required, to the stokers in front of the boilers. If the coal cars have drop bottoms, the unloading is quickly done by opening the drops. If a car does not have a drop bottom, it is unloaded by a 2-yard clam-shell bucket operated from an overhead crane.

In its passage through the boiler-house the coal is handled on five different levels and in nine operations, as follows: Delivered on the unloading track, dumped into first receiving hopper, run through crusher, discharged into conveyor, elevated to second receiving hopper, drawn off to stokers, dumped from back end of chain grate to ash hopper, discharged into empty coal cars, hauled out of train shed. The boiler-house is so designed and equipped that at no point in the handling of the great volume of coal that daily passes through it is it necessary to use manual labour.

The boilers are arranged in rows of 10 each, facing each other on opposite sides of a common firing-room, so that one set of firemen and water tenders can look after 20 boilers. Each 10 boilers are served by a tile-lined steel stack 17ft. inside diameter, and extending 275ft. above the boiler-room floor. In designing the boiler furnaces, it was recognised that they must burn the smokiest kind of soft coal screenings practically without smoke. The fundamental principle in smokeless furnace design is to provide a chamber of high temperature and of sufficient length or volume to ensure complete combustion of the luminous flame before it comes in contact with the boiler tubes. This can be done perfectly in a furnace having a tile roof, but unfortunately two other things, both undesirable, are also accomplished. The changed gas passage restricts the draught and reduces the boiler capacity; at the same time the furnace temperature is so high that the expense of maintaining furnace walls and arches is greatly increased.

In the design used at the North-west Station the boilers were set with the high end of the sloping tubes to the front and 10ft. above the grate, the expectation being that this great height would serve as a vertical combustion chamber, with ample capacity to give the flame time to burn out before it reached the tubes; the draught would not be restricted and the brickwork would be conserved by the temperature being kept down through the absorption of radiant heat by the exposed tubes. The second battery of boilers were set like the first, with the exception that they were given a horizontal gas pass (see Fig. 2), the purpose being to give the two designs thorough comparative tests and adopt for the station that design which, all things considered, proved to be the best.

Each boiler should be able to easily generate 30,000lbs. of steam an hour, or 70 per cent. more than normal rating, and this rate of steaming will require a rate of coal burning of 4,500lbs. an hour under each boiler, or 75lbs. a minute. This means that in each second of time 300 cub. ft. of air passes through the grate and in the heat of the furnace becomes 1,500 cub. ft. It therefore whisks itself into and out of the furnace at a rate which necessitates combustion to be almost instantaneous if complete. With 60 boilers, all running at the maximum rate, the amount of air entering the grates each minute is over 1,000,000 cub. ft. If this were all drawn through the boiler-room on a winter day, the firemen would be obliged to go out of doors to get warm; but to avoid such unpleasant draughts of cold air as would otherwise be created, provision is made to admit air directly under the grates from the train-shed below.

These boilers have each 5,800 sq. ft. of water heating and 350ft. of steam superheating surface, and are equipped with travelling chain grates of 115 sq. ft. area. Steam is raised to a pressure of 250lbs. and is superheated 125°. Steam is taken from the boilers through 6in. pipes connected with a 16in. header supported on roller bearings in the header room. Connecting the steam headers is an 8in. crossover, by means of which steam from one unit may be supplemented with steam drawn from an adjoining unit. Each battery of boilers is provided with two boiler feed pumps. These are 5in., 3-stage Worthington centrifugal pumps driven by Curtis steam turbines at 2,300 revs. per minute, and have a capacity of 700 galls. per minute against a pressure of 285lbs. The feed water is pumped from the condenser at a temperature of about 75° into a closed feed-water heater of 4,000 sq. ft. heating surface, in which it is heated by exhaust steam from the auxiliaries. A float valve at the top of the heater regulates the admission of make up water into the condenser.

The turbine-room when completed will measure 290ft. long, 70ft. wide, and 55ft. high. This allows for a turbine spacing of 44ft. from centre to centre. As the turbines measure only 15ft. 5in. maximum outside diameter, there is ample floor space for the auxiliaries. Spanning the turbine room is a Morgan travelling crane of 110 tons capacity. The turbines (Fig. 3) are of the well-known vertical Curtis type, rated at 20,000 kw. capacity, and run at 750 revs. per minute. They are 6-stage, each wheel having two rows of buckets built in sections and riveted to the disc which forms the central part of the bucket wheel. The first three wheels have 28 double bucket sections of 24 buckets each, and the last three have 28 double bucket sections of 20 buckets each, making a total of 7,392 buckets. These buckets vary in length from 1¼in. in the top row of the first wheel to 1⅜in. in the bottom row of the sixth wheel. The outside diameter of the sixth wheel is 13ft. 2in., and therefore has a peripheral velocity of over 500ft. per second, or about 6 miles per minute. The guaranteed steam consumption, with steam at 250lbs. pressure and 100° superheat, is 14lbs. per kilowatt-hour at loads of 10,000 kw. and 20,000 kw. and 13·45lbs. at a load of 15,000 kw.

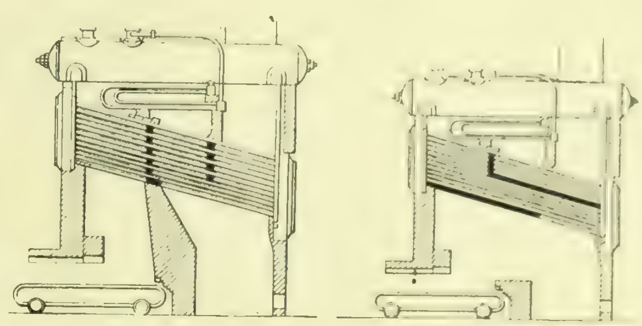


FIG. 2. ALTERNATIVE ARRANGEMENT OF BOILERS WITH VERTICAL AND HORIZONTAL PASS FOR THE GASES.

The weight of the steam end is 200 tons and of the generator 230 tons, making a total weight of 430 tons, of which 100 tons is in the revolving elements. This great weight is supported on the step bearing, the two halves of which are kept from direct contact by oil which is forced into the bearing at a pressure of 800lbs. per square inch to which the pump pressure of 1,200lbs. is baffled down. Floating on this oil system is an accumulator weighted to 30 tons. Should the accumulator sink to a predetermined level, owing to failure of the steam pump, it would automatically put into operation an auxiliary electrically-driven pump.

The base condenser on which the turbine rests is designed to condense 280,000lbs. of steam per hour, using for each pound of steam condensed 75lbs. of cooling water, whose temperature will be raised 14° Fah. in passing through the condenser. The condenser contains 7,600 1in. tubes 17ft. long, comprising 32,000 sq. ft. of cooling surface, as compared with 58,000 sq. ft. of water heating surface in the boilers. A 20in. by 30in. Corliss engine, running at 120 revs. per minute, drives the circulating water and dry vacuum pumps. The circulating water pump is a 36in. volute of a capacity of 40,000 galls. of water per minute against a head of 20ft. The condenser with its inlet and discharge pipes form a closed siphon, so that after the system is once filled with water the lift in one leg is balanced by the fall in the other, and then the circulating pump has only to overcome the friction and inertia to circulate the water.

The cylinder of the dry vacuum pump, which is mounted in tandem with the steam cylinder of the Corliss engine, measures 28in. by 30in. and at the speed mentioned has a displacement of 2,550 cub. ft. per minute. Such a volume of air drawn from a condenser having an absolute pressure of 1in. would shrink to 80 cub. ft. at atmospheric pressure, or about 7lbs. of air. Water of condensation is removed from the condenser by a 5in. horizontal 2-stage Worthington centrifugal

turbine-driven pump with a capacity of 660 galls. of water per minute.

The generator mounted above the turbine is of the revolving field type and generates 25-cycle, 3 phase current at a pressure of 4,500 volts, which is stepped up by transformers to 9,000 volts. The revolving field has four poles and weighs 52 tons. The armature is star wound and has a continuous rated capacity of 2,570 amperes per phase. The peripheral velocity of the turbine-driven revolving field is five times as great as in the case of the reciprocating engine, and the amount of work done per unit of mass for the whole field is proportionally increased. Moreover, the barrel-shaped armature in which the turbo-generator field revolves does not permit of the natural ventilation which occurs in the case of an engine-driven field of large diameter revolving in almost free air. For these two reasons forced ventilation is necessary with a turbo-generator, and is created by a fan mounted on the main shaft above the generator and set to blow a strong

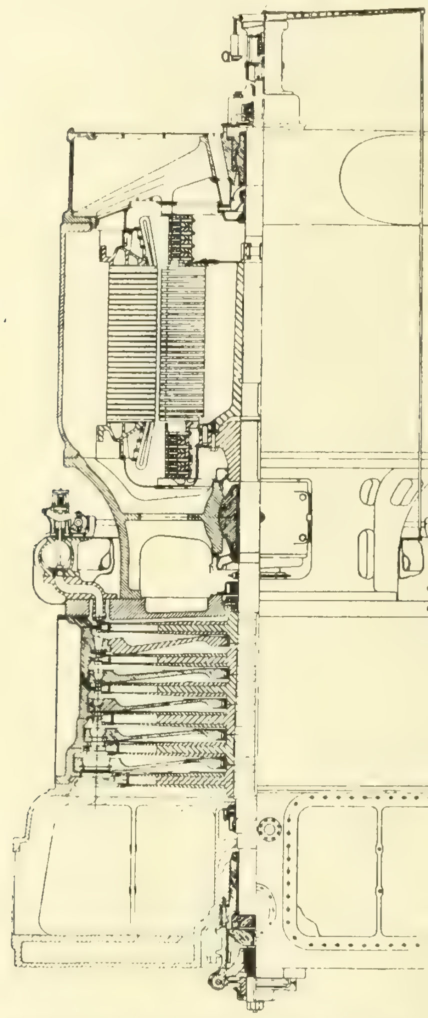


FIG. 3. SECTIONAL ELEVATION OF CURTIS STEAM TURBINE.

blast of air through the field and armature. The efficiency of the generator is very high (96 per cent.), and yet because of the great amount of energy transformed in the generator, the heat evolved is equal to that resulting from the perfect combustion each hour of 270lbs. of coal of the quality that is used in the boiler room. The capacity of a generator is limited by the temperature of its insulation, and may be increased as means for keeping down the temperature of the insulation are improved. To render the relatively small turbo-generator safe with the great loads which are put upon it, the air for the forced ventilation is drawn not from the turbine room, but from outside of the building.

For excitation purposes 75 kw. at 125 volts is required. In the completed station there will be four exciters. Two of these will be of 300 kw. capacity each, driven by a 2-stage horizontal Curtis steam turbine running at 1,500 revs. per minute and generating current at 125 volts. The other two, of 200 kw. capacity each, will be driven by 3-phase, 25-cycle, 220 volt motors running at 750 revs. per minute. In addition there will be two storage batteries of 70 cells each, with a capacity of 1,000 ampere-hours. The operating gallery is located in a bay projecting into the turbine room, and from here the operator has a clear view of the entire turbine room floor. The generator control switches are mounted on a bench board, and the line control switches and all instruments are mounted on vertical slabs above the bench board.

Slow speed engine-driven generators, by their mass and construction, have inherently such poor automatic regulation that any sudden reduction in the resistance of the circuit supplied is accompanied by an increased output of current at a considerably reduced pressure. This is due to the choking or reactance effect of the armature. This feature of such generators resulted in serious fluctuations of pressure with fluctuation of load, and was naturally considered an objectionable quality. Central station managers were, therefore, continually asking manufacturers for machines having better inherent regulation. With the advent of the high speed turbine it was found possible to build a generator whose reactance was only one fourth or one-fifth of that of the slower speed generators. This was thought to be a highly desirable improvement, and the utmost advantage was taken of the new design to keep the reactance as low as possible. But when such generators of large sizes were built and connected to a common set of bus-bars, it was found that nearly the whole energy stored in the high speed revolving masses would be instantly hurled into any near by short circuit which occurred, the energy output of the machines for the moment being perhaps 20 times normal.

Such violent surges were so destructive to generators, switches, bus-bars, lines, and connected apparatus that it was found necessary to restore to the circuit nearly as much reactance as had been gladly eliminated. In the case of the Fisk Street machines, this was accomplished by installing in each of the three armature leads to the bus-bar a 6 per cent. reactance, that is, a coil of wire supported on a concrete and wood frame, whose choking effect, together with the 2 per cent. reactance in the generator, at full load of the generator is equal to 8 per cent. of the voltage generated. This effect, which is unobjectionable at normal loads, increases with the square of the current flowing and, therefore, in times of trouble affords protection which is ample and at the same time automatic. In fact, one of the 12,000 kw. Fisk Street generators was repeatedly short-circuited through a set of these reactances without harm to generator or coil.

At the North-west Station the additional reactance needed was introduced into the circuit in the auto-transformers, which step up the pressure from the machine voltage of 4,500 to the system voltage of 9,000. These transformers are installed in a separate building, between the turbine room and the switch house. Each transformer is installed in a separate fireproof compartment, and is of 3,333 k.v.a. capacity. They are water and oil cooled and contain 1,700 galls. of oil. Water is circulated through pipes immersed in the oil at a rate of 16½ galls. per minute. Each tank has an emergency drain, by means of which it can be emptied of oil in a very short time. The efficiency of these transformers is very high, being 99·4 per cent. at half load and 99·3 per cent. at full load. They are 13ft. high, 9ft. long, and 5ft. wide, and weigh, with the oil, 25 tons.

To the east of the transformer house is the switch house, a three-storey building containing all the oil switches, high tension bus bars, and instrument transformers. On the first floor the bus bars, cables, bells, and generator leads are installed. The line and generator buses run east and west, and the main and auxiliary buses north and south. The second floor contains the oil switches, the pots of which are built in a single row instead of a double row. This arrangement provides greater safety, in that each oil pot is separated from the adjoining one by a concrete partition. Nineteen switches are provided for each unit, nine of which are line switches, eight are bus and tie switches, and two generator switches.

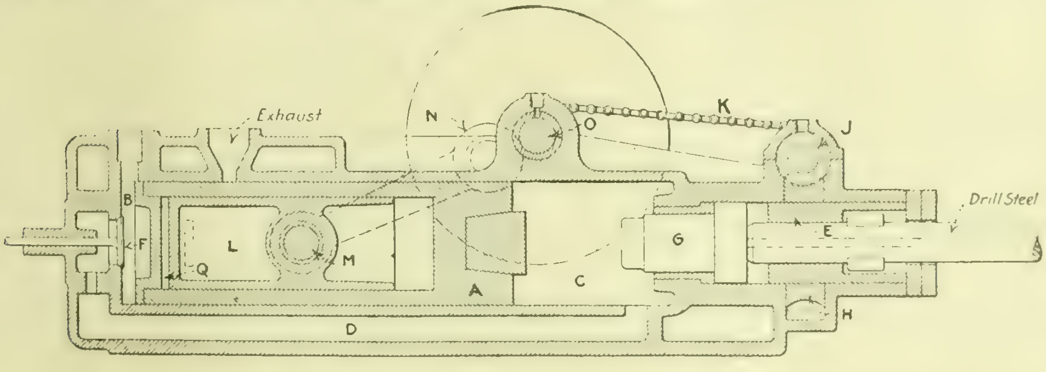
The generating station just described is the most modern of any in existence, and was designed by engineers who have been engaged all their lives in designing power houses and power house equipment. No expense was spared to make this installation the last word in the art of converting the energy of coal into electrical energy. The station was de-

signed for six units, two of which were to be included in the first installation and the remaining four to follow soon thereafter, so that the station when completed would contain a symmetrical, up to date equipment of the largest size and highest efficiency; but alas for the best laid plans of men between the dates that the plans were finished and the station was put in service, as great strides were made in the art as had been made during any period of equal length in its history. The North west Station is doing all that was expected of it, but within a little more than a year from the time it was put into service its equipment will be eclipsed by an installation at Fisk Street of larger and more efficient boilers, and larger and more efficient turbines. The indications now are that the equipment which will be installed at the North west Station in the future will be of an entirely different type from that now in, and we may even hope it will be as great an improvement over the newer Fisk Street turbines as those are expected to be over the machines discussed in this paper.

A GASOLENE ROCK DRILL.

A NEW gasolene rock drill, which does not require a power plant and pipe line installations, has been designed and patented by L. L. Scott, of the Scott Drill Company, 1,013, Chestnut Street, St. Louis, Mo. The new drill is of the hammer type, in which the drill steel has no reciprocating motion but receives a rapid succession of blows upon the end, these blows being transmitted from the piston of the operating cylinder. The drill is in effect a single-acting 2-stroke cycle gas engine, and a crank shaft and flywheel are used to effect the return stroke of the piston. In order to permit the piston to deliver a fully effective and uncushioned blow, it is essential that it should be entirely free from connection to the crank shaft or other fixed part at the moment when the blow is struck. The way in which this is effected is one of the special features of the machine and can best be explained by reference to the accompanying sectional view, for which, along with the following description, we are indebted to "Engineering News."

The cylinder has a long hollow piston A, the space in the rear of which at B is the explosion chamber, while the space C at the forward end of the cylinder is the compression chamber in which the charge of air and gas is compressed to force it into the cylinder through a channel D outside the cylinder



SECTIONAL ELEVATION OF SCOTT GASOLENE ROCK DRILL.

wall. The front cylinder head forms a guide for the drill steel, and in it is mounted the chuck E for rotating the drill. In the rear head is the check valve F through which the explosive mixture is admitted to the chamber. The hammer piston is a long hollow plug, closed at both ends, having in its forward face a hammer head designed to strike a sliding block G in the front cylinder head, through which block the blow is transmitted to the end of the drill steel. The rotating chuck has slots to receive lugs on the drill rod, and has a worm wheel H around its outer face, gearing with a worm J on a cross shaft driven by a chain K passing around sprockets on the main and cross shafts. The hammer piston "floats" in the cylinder, having no fixed connections to limit its stroke or movement. Within this piston is fitted a second piston L of fixed stroke. On the side of this inner piston is a cross pin M which projects through a slot in the hammer piston and in the cylinder wall. This pin carries one end of a connecting rod N whose other end is fitted to the crank pin of the main shaft O, which shaft lies above and across the cylinder. Upon this shaft is the flywheel P. A port in the side of the main piston permits air to enter the space Q between the rear ends of the inner and outer pistons to provide a cushion. The exhaust opening is in the top of the cylinder near its rear end.

During the backward stroke of the main or outer piston, the explosive charge is admitted to the space C in front of it, and with the next forward stroke this charge is compressed and forced through the passage D and admission valve F to the explosion chamber, or space B at the rear of the piston. With the second backward stroke this charge is compressed within the rear chamber and a second charge is admitted to the forward chamber. At the end of this stroke the compressed charge at B is fired, driving the piston A forward so that its hammer head strikes the block G, which transmits the blow to the drill rod. The contact with the block occurs just before the crank of the main shaft reaches its dead centre, and the momentum of the flywheel causes the crank to continue its motion so that the inner piston slides forward within the main piston, allowing the crank to pass the centre without shock to its bearings. As this inner piston moves forward it uncovers the cushioning port above mentioned and admits air at its rear, which is compressed within the space Q, as a cushion on the return stroke of this inner piston until the pressure is such that the main or hammer piston is moved back with the other. With this arrangement the main or hammer piston is entirely free from the main shaft at the moment when it makes its blow on the striking block. Both the piston and the block are of vanadium steel. The cylinder slides in its mounting and has the usual screw-feed arrangement.

As will be seen from the above description, the drill engine is of the single acting 2-stroke cycle type, of simple construction. The inlet and outlet ports are not opposite each other, so there is no opportunity for back firing. The speed can be as high as 3,000 revs. per minute, but can be regulated by the operator as desired. The machine runs with very little vibration when drilling. Cylinder lubrication is provided for by adding a small amount of oil to the gasolene (1 pint to 5 galls.). It will rarely be necessary to provide for carrying away the exhaust, and in fact gasolene locomotives with much larger engines work in mines and tunnels without causing trouble. In close ground the exhaust may be piped into a water sump or to the mouth of the shaft or tunnel, and if the exhaust pipe should be several hundred feet in length, a small suction blower may be put at the end in order to relieve back pressure. A tank located near the drill holds about 2 galls. of gasolene and 15 galls. of water for the cylinder jacket and for washing out the drill hole. Small hose lines run from the tank to the machine. The only other apparatus required is the small battery supplying current for the electric ignition apparatus.

The drill is made in four sizes. The smallest, which can be held in the hand and is adapted for such work as block holing, weighs 18lbs. The others are carried on mountings; one of these weighs 85lbs., and drills holes 4ft. to 5ft. deep. The next size weighs 140lbs. and drills holes 8ft. to 10ft. deep. The largest size weighs 265lbs. and drills holes 14ft. to 20ft. deep. These weights are exclusive of the tripod or column mounting. The cylinder diameter is 2in., 2½in., and 3¼in. in the three mounted sizes, respectively. The average gasolene consumption of the largest machine is 2 galls. for a 10-hour run. In hard limestone it will drill 80ft. of hole per day. For starting, a 2¼in. bit is used, and the hole is finished with a 1½in. drill. Two types of drill rods are used. One of these is a hollow cylindrical rod, and at each stroke a portion of the exhaust is used to force water to the end of the hole, thus removing chips and dirt and keeping a clean rock surface to receive the blows of the drill. The other rod is solid, but has a spiral thread on the surface which acts as a conveyor to remove the chips from the hole. It is claimed that the gasolene drill with 3 h.p. has a capacity equal to that of an air drill requiring some 20 h.p. at the power house.

THE PRESERVATION OF METALS USED IN MARINE CONSTRUCTION.*

BY LIEUTENANT COMMANDER FRANK LYON, U.S.N.

In taking the above title for this paper the writer intends to apply it to vessels only under the two subdivisions: The metal of the hull; the metals of the engines, boilers, and machinery accessories. The causes of the wasting away of such metals are three: (1) Corrosion; (2) abrasion; (3) erosion.

Corrosion is the most serious of the three, is ever present, and is the most difficult to combat. Metals are weakened by all of the three causes and also by the continued variation of stresses in them. These variations tend to open up and emphasize the inherent defects in the metals due to segregation of the impurities in them and to their different physical characteristics which are induced or produced by the different temperatures at which they are worked during stages up to and including the finished article. Corrosion, the chemical decomposition of metal, is due to the differences in electric potential between the metal and the liquid or moisture that wets its surface. It is produced only when the metal is wet or moistened by some liquid of lower potential than metal itself. Metals that are absolutely dry do not corrode, and wet metals corrode only on their wetted surfaces.

In this paper it is assumed that there is some definite, absolute zero of electrical potential similar to the absolute zero of heat, and that all bodies and liquids have some definite potential at each temperature. When a metal at a certain potential is immersed in a liquid of lower potential the metal dissolves with the liquid and raises its potential; if the metal remains in solution in the liquid until the potential of the liquid solution is the same as that of metal, the solution is then saturated and no further dissolving takes place until the conditions of temperature or liquid solution are changed. If the potential of the liquid is the higher, the liquid exerts an electrical pressure on the metal but does not cause it to dissolve. If the metal can dissolve in the liquid but is thrown out of solution as rust by some chemical agent inherent in neither the metal nor liquid, the dissolved parts do not raise the potential of the solution and the dissolving goes on to the extinction of the metal. The same results will be attained if the liquid is changed as fast as the metal dissolves into it, such as a plate on the side of a ship in a large body of water.

The diffusion of the dissolved parts of any substance in a liquid is believed to be due to the fact that the potential of the liquid is raised at the dissolving point and that the tendency of all parts of any liquid body at different potentials is to equalise or come to a common potential. This in itself tends to keep the potential of the liquid at the dissolving point down until the potential of the whole body of the liquid is brought to the same as that of the dissolving substance. That is, the liquid becomes a homogeneous solution throughout its whole mass by diffusion of the dissolved parts into the solvent. If a metal has all of the points in its wetted surface at the same potential, and that potential is higher than that of the liquid by which wetted, it will corrode or dissolve at all of its points and general corrosion is said to exist. If the potentials of some of the points are higher and others lower than that of the liquid in which it is immersed, it will corrode only at the points where its potential is higher than that of the liquid, and local corrosion is said to exist with pitting of the metal as a result. The potentials of pure metals and liquids vary with their temperatures and with the way in which they are stressed, and those of impure metals and solutions vary in the same way, and also with the way in which the ingredients vary with the temperatures. That is, an alloy would not have the same potential that any one of its ingredients would have at the same temperature, but one common to that of all of the ingredients. Also, the potential of a solution at any temperature would not be the same as that of either the liquid or dissolved substance at that temperature, but at some one potential common to them both. In other words, the theory of potentials is assumed to be similar to the theory of heat. If two bodies, solid, liquid, or gaseous, at different temperatures are brought near each other they assume a common temperature in proportion to the amounts of heat each contains, and it is easily conceivable that the same objects at different electrical potentials would come to some common potential in proportion to some inherent qualities of the two bodies in question.

If two metals are connected by a metal conductor and they are immersed in a liquid, and if one of them is at a potential higher than the liquid and the other at a lower one than the liquid, the higher one dissolves into the liquid and raises its potential, the liquid discharges its potential to the one lower than itself, and a current flows and the original condition is maintained. If the metal connection is broken, then the metal of higher potential raises that of the liquid, which in turn raises that of the metal of the lower potential, and eventually the potential of the whole becomes equal to that of the higher metal, no current flows, the original condition is destroyed, and the metal-water-metal series is polarised. A metal with different potentials at points in its surface immersed in water or a water solution acts in the same way. If all of the points are higher than that of the solution they all corrode until the potential of the liquid is raised to that of the lowest point on the metal. As the points of higher potential dissolve into the liquid and tend to raise its potential, the liquid then discharges its potential to the points in the surface lower than itself, a current flows from the high point to the liquid, from the liquid to the metal at the points lower than itself; the circuit is then complete and local corrosion as pitting is the result.

This discussion on corrosion is made necessary by the subject matter that is to follow. The statements made above will be referred to in many places and would not be understood unless explained beforehand.

Abrasion is due to the wearing away of one substance by rubbing against another. In vessels' hulls it is mostly noticeable on the bows where rubbed and abraded by the anchors and chains. In their engines and machinery it is noticeable in the bearings, guides, and similar construction, especially when not properly cared for. Its effect on the hull material is not serious and cannot be prevented in wake of the anchors and chains. There is no danger of damage from that source.

Erosion is due to the wash or scouring action of liquids or gases over metal at high velocities. With the exception of valves, and maybe in a few other places about the machinery, its effect will not cause sufficient loss to be noticeable.

Metals used in the construction of the hulls of vessels are: Steel for plates, angles, beams, rivets, struts, and external and internal braces and hull fittings. Composition castings for sea chests and propellers. The compositions generally used are manganese and phosphor bronzes; monel metals—nickel bronzes—and an 88 copper, 10 tin, 2 zinc bronze. Steels are extremely variable in the way in which they corrode and in their effect upon other steels to which they are connected by metallic contact. These variations are due to the differences in chemical compositions and to the difference in state of stress of the molecules of the metals in their wetted surfaces. These different stresses are in turn due to the different workings the metal has received, the temperatures at which it has been worked, and to the heat treatment finally given the finished product. Two pieces of steel from the same plate may vary perceptibly in the way in which they corrode and in the loss of weight per unit of area in a unit of time due to the above causes; that is, certain constituents may be segregated over the surface of one piece and not over the other, or different stresses may exist in the two surfaces, due to the different ways in which they have been worked or treated. An angle bar corrodes more quickly than a plate of steel of practically the same constituents; a bent plate or angle bar corrodes in and near the bend more quickly than the straight part. There is always more corrosion around the entrance, run, and bilge of a vessel where all of the hull plates and frames are bent, than along the straight body. A rivet that has been hammered and upset corrodes faster than the same rivet before it was hammered. The assumption that any piece of steel is a homogeneous body either as to chemical contents or as to physical stress is one that can very easily be disapproved by sufficient chemical analyses and by photomicrographic work. The writer was much surprised to note the differences in chemical composition and photomicrographic results in a boiler tube, samples taken (1) over the expanded surface, and (2) over the unexpanded surfaces. He was also surprised to see the different ways in which boiler tubes corroded over the same areas, as shown both by Cushman and Walker's ferroxyl

* Paper read before the American Society of Naval Architects and Marine Engineers.

mount and by actual immersion. Steels are of higher potential than water at ordinary atmospheric temperatures.

Copper and copper compositions vary in the way they corrode. These variations are due to chemical compositions, variable temperatures, and to the way in which they have been worked producing stresses in the surfaces of the finished product. At ordinary atmospheric temperatures copper and its compositions are of lower potential than water, *i.e.*, they are said to be electro-negative to water. As their temperatures are increased or as they are stressed to higher degrees their potentials increase faster than does the water in which they are immersed, and if the temperatures or stresses are raised sufficiently they become of higher potential than water and corrode or dissolve similarly to steel. As a proof of this, from observation on shipboard for 13 years, copper and composition piping corrode faster at the bends and near flanges than at the straight parts, and pipes in which temperatures are different in places, such as feed piping through feed heaters, condenser and circulation piping, and other piping which is at different temperatures over different parts, corrode faster than do the fire mains and other piping which are at the same temperature throughout. Two pieces of copper or composition cut from the same plate, treated in the same way, may show no difference of potential when immersed together in water and connected through a potentiometer. Then if one piece is removed and hammered, worked or heated, and replaced, it will show that it is electro-positive to the unworked piece, and it will corrode if placed in water of a certain temperature in which the other piece may or may not be affected according to the treatment and chemical composition of the original sample. Composition castings are generally of a very uniformly stressed surface, due to the heat treatment naturally given in cooling. Those placed as sea chests in ships require no protective coating and seldom, if ever, give any trouble, and the highest temperatures to which they are subjected are not sufficient to raise their potentials to equal that of the sea water in which they are immersed. If the copper compositions are segregated and these segregated spots are of higher potential than sea water they dissolve away and pit to the depth to which the segregations extend.

These compositions are negative or lower in electrical potential than ordinary or sea waters, while steels are electro-positive or of higher potential than the same waters at ordinary temperatures. If the bare steel is immersed in the water it will corrode or dissolve at all points in its wetted surface, while the composition casting in the same waters will not corrode at any of its points. If these two metals are connected by a perfect metallic contact and immersed in the same water the rate of corrosion over the steel will be greatly increased. The rate at which it will be increased all over its surface will depend upon the perfection of the metallic contact; if there is no such contact the presence of the composition will not increase the rate of corrosion on the steel, no matter how close together they may be. If the steel is covered with a moisture-proof paint and the same contact as above made, it will not corrode when connected by a perfect metallic contact with the compositions, but if the film of the moisture-proof paint is broken so that any part of the steel surface is exposed to the water it will corrode rapidly over the exposed part.

Where these composition castings are secured to the steel hull of a vessel it is customary to secure plates or rings of rolled zinc as a protection to the steel, the idea being that the zinc being of higher potential than the steel, will corrode and preserve the steel. That this assumption is thought to be correct is evidenced by the great use of zincs at a very large cost in these places. Yet the writer has failed to see that the assumption is positively correct for the following reasons: (1) Zinc quickly corrodes and becomes covered with zinc oxide, and zinc oxide from boiler, condenser, and hull zincs has been found to be electro-negative to steel in every case tried. (2) In no case has the writer ever had a piece of steel connected to a zinc plate corrode less in the same water in 30 days than a piece of steel from the same plate placed alongside the first plate but not connected to zinc. (3) The steel around the sea chests of the bottom blow discharges, if properly painted, does not show more corrosion than does that around the other discharges, and the writer has never seen a ship docked that had any zinc in the bottom blow discharges, they evidently having deteriorated and been blown out soon after the previous undocking. (4) It has been noticed on many occasions that the only steel attacked by corrosion in the vicinity of the zinc plates was that of the steel screws holding the zincs in place. Therefore the writer fails to see the necessity of the zinc protectors, especially as he has just seen the bottom of a ship on which, after having been in the water over six months, there were no signs of corrosion at any point when the paint film was unbroken except on the zinc.

The use of zincs and other metals electro-positive to steel in galvanising, electro plating, or other similar covering processes, as a preservative for it, when continuously immersed in water, is a dangerous one and is not to be commended for the following reasons: (1) The metal covering must be electro-positive to the steel or metal to be protected, therefore it is more soluble in water and will dissolve more quickly. (2) When the steel is once exposed to the action of the water it corrodes rapidly over the exposed surface and if not stopped by some similar covering it will pit through before other surfaces are uncovered. (3) For hull and ship fittings generally a surface once exposed cannot be again covered. (4) The stable oxides of all metals are lower in the potential series than the pure metals, therefore the oxide of the coating may be lower in potential than the metal to be protected and actually does harm instead of good where the steel is exposed.

For the protection of the hull construction it therefore remains only: (1) To provide the most homogeneous metals possible both in regard to chemical composition and physical structure. (2) Paint the completed structure with a complete film of the best anti-corrosive paint that can be obtained, after having cleaned the surfaces of all foreign matter and rust and dried them thoroughly. After this film of paint is dried give the surfaces a second coat of the same paint; after this coat is dry paint with an anti-fouling paint for all outboard, under-water structures, and with the best moisture-excluding paint for all other surfaces. (3) Dock frequently and remove any rust that may be found and repaint as may be necessary. (4) On inboard structures remove all paint that shows active corrosion under it and when thoroughly cleaned and dry repaint as before.

The subject of proper painting is a very important one and one that must be thoroughly understood to obtain good results. There are three necessary points that must be observed and understood as follows: How to paint, when to paint, and what kind of paint to use for the different conditions the paint has to stand. How to paint involves the question of the proper preparation of the surfaces, the proper preparation of the paint, and a proper spreading rate of the kind of paint used. When to paint involves the question of the dryness of the surfaces and the atmospheric conditions in the vicinity of the surfaces. What kind of paint to use involves the question of whether the paint is to be used (1) as a protection to the metal—anti-corrosive and waterproof paint—(2) as a cleanser of the paint film of marine growth—anti-fouling or poisoned paints—(3) as a decoration to the structure—covering and colouring paint.

In any of the above cases the paint film when dry should have about the same coefficient of expansion as the metal to be covered, or the painting will crack or become loosened from the surfaces, and any good effect, even unto decoration, will be lost. An anti-corrosive paint is one that, when well dried, is impervious to moisture and keeps the metallic surface dry so that no active corrosion can take place, and one that, when moisture does percolate through it to the metal, dissolves and raises the potential of the enclosed water to a point as high or higher than that of any metal exposed to it. To perform this last function the pigments of the paint must be higher in the electromotive series than the metal to be covered, and to perform the first the pigments and solvent must form a homogeneous film over the whole of the covered metal. An anti-fouling paint is one that, when any marine growth sticks on its surface, either poisons the growth and allows it to drop off or dissolves under the growth due to its secretions and allows it to loosen and float away. Many good anti-corrosive paints are not good waterproof ones; therefore unless the anti-corrosive paint is a good waterproof one, it should be covered with a good waterproof paint, for the protective effect of a non-corrosive paint is obtained at the expense of the paint unless it is also a good waterproof one. As soon as enough of the paint is dissolved off to enable a free circulation of water to the surface of the metal the anti-corrosive effect is lost.

Proper painting is a most important aid in the preservation of metals and no effort should be spared to obtain it. The first cost of painting for the protective effect must be disregarded and the best paint obtainable for the purpose used and applied with the greatest care. There is a general tendency in some directions to regard painting as only for decorative purposes and to consider that the cheap paints frequently applied are the best. Even for decorative purposes, this is not true, because a proper paint properly applied will generally last at least three times as long as an improper one at half the price. Judging from the amount of surface to be covered, the conditions of its service, the number of men to do the work, and the other work they have to do, the best paint, properly applied, is none too good and should be obtained at any cost.

As active corrosion cannot take place on dry metals it may often be better not to remove a good film of paint that has been put on over dry dust, and through which no signs of active corrosion are visible, than to spoil the paint for the purpose of removing dry and therefore harmless rust unless it is perfectly sure that a properly dried paint film can again be obtained over perfectly dry metal. The writer has on several occasions done more harm than good by removing good dry paint films previously put on over dry rust because he could not get the surfaces dry and a proper film of good paint to stick to them.

The metals used in machinery, boilers, and their accessories and piping are many, such as: Cast iron for cylinders and engine housings; steel for steam pipes, boilers, shafting, tanks, evaporators, condensers, feed pipes, and general piping; composition for water boilers of pumps, water pipes, valve fittings, boiler fittings, condenser tubes, and in other places; copper for small piping and in other places; monel metal for valve fittings, pump liners, pump rods, and such other places; cast steel for superheated steam valves, slip-joint castings, &c.; lead as a lining for iron or steel pipes. Other metals are used, but the above are the principal ones. The same observations apply to these metals that can be painted, as previously stated, for hull materials.

Oil films are moisture-proof when applied to dry metals, therefore there is very little, if any, corrosion taking place about an engine when it is in use. Paint around the usual main engines and their framing is unnecessary unless the engine is to be laid up for a long period, and, if used, is for the purpose of decoration only. The external sides of pipes, feed heaters, condensers, boilers, evaporators, and tanks can be protected by proper paints. The internal or water side of the above cannot be protected by paints nor is it generally believed by any other means, though lacquers, galvanising, lead lining, and other means have been tried on pipes, they have all proved unsatisfactory, in some cases due to the unequal coefficients of expansion of the coating and metal, in some to the solubility of the lacquer, and in others to the fact that the metallic coating cannot be properly applied to the finished article. As the life of piping, boiler plates, and other parts is no greater than the weaker part, the piece fails when improperly protected. Boiler, condenser feed-water, distiller, and evaporator tubes cannot be protected on either side by paints, lacquers, and coatings. Therefore all such parts should be made of homogeneous metals properly heat treated after being finished and then fitted properly so that the least possible internal strains are brought into it due to the fitting.

It has been definitely proved that any water made alkaline enough to show 3 per cent. of normal alkalinity with calcined sodium carbonate is non-corrosive to steel at all temperatures up to 422° Fah. Therefore if the water in the boilers, tanks, evaporators, and feed piping is kept at or above that strength with sodium carbonate at all times no corrosion will take place, while if the strength is allowed to fall to about 1·8 to 2·5 per cent. bad pitting will take place. In trying to reproduce the pitting continually taking place in boilers, tanks, piping, and on bilge plates with acid solution, or plain sea or distilled water, the writer failed in every instance on three grades of nearly pure irons, three grades of boiler steel, and on four grades of cast iron. It was easy to produce such similar pittings on all of them when immersed in weak alkaline and very weak carbonate solutions.

For the above reasons it is believed by the writer that much more harm is done in enclosed metal vessels by water made slightly alkaline, either artificially or naturally, than is ever done by the small percentage of acids that ever enters the average boiler. Boilers and other water-containing metal vessels or conduits containing acid water will go to pieces quickly, practically all over at the same time; those containing sea or distilled water will go to pieces all over at the same time but very slowly; those containing alkaline water of a strength not high enough to stop all corrosion will go to pieces in the weaker places, while other parts or places will remain perfectly good. If the percentage of alkalinity is high enough no corrosion whatever will take place. The reason for this is believed to be as follows: (1) Water has a certain definite potential at any definite temperature. (2) Pure distilled water has a potential lower than that of steels, irons, and some alloys. (3) Acids added to pure distilled water at any temperature decrease its potential. (4) Alkaline substance dissolved in pure distilled water increases its potential. (5) The decrease of the potential of water when an acid is dissolved in it is due to the fact that the negative ion of the acid is lower in potential than that of the hydroxyl OH of water, the H ion being common. The increase in potential of water when an alkaline substance is added to it is due to the fact that the metallic or positive ion of the alkali is higher in the potential series than hydrogen, while the hydroxyl or negative ion is common to both. (6) When any metal is wet by any water solution, if the potential of the solution is (*a*) higher than that of the metal at every point on its surface, the metal will not corrode; (*b*) higher than some points in the metal surface and lower than that in others, the metal will corrode only over the areas where the potential of the solution is the lower; and it will corrode faster over those points than it would if immersed in distilled water alone, due to the fact that though the difference of potential between that of the metal and that of the alkaline solution is less than it would have been in distilled water, yet the conductivity of the water has been greatly increased by the addition of the alkaline substance; (*c*) lower than that of the metal at any point it will corrode all over at the same time, faster over the higher potential points than over the lower ones. The rate of corrosion over all of the points will depend both upon the difference of potential between the metal at the point and the solution, and also upon the conductivity of the solution. As the alkalinity of the solution decreases the difference of potential between the metal and the water increases and the conductivity of the solution decreases until pure water is reached. Any addition of an acid then increases the difference of potential between the metal and the solution and also increases the conductivity of the solution. When considered with a given metal the potential of some alkaline solutions increase faster with a rise in temperature than does that of the metal, therefore a solution that may not be dangerous at ordinary atmospheric temperature may be strongly active to the same metal at higher temperatures.

Also a solution that may be strongly active to metals at atmospheric temperatures may be non corrosive entirely at still higher ones. The converse may be true with some of the alkaline substances, that is, a rise in temperature may not increase the potential of the solution as fast as it does the metal and a safe solution at atmospheric temperatures may be unsafe at higher ones. In the writer's experiments with alkaline solutions the general rule was that a one one-hundred-thousandth and a one ten-thousandth normal concentration of alkaline solutions decreased the rate of corrosion of irons and steels slightly below that in distilled water and caused no pitting, while the one one-thousandth and one-hundredth concentrations increased the rate above that and caused very active local corrosion or pitting until the 2·6 per cent. normal concentration was reached, when all corrosion stopped.

Cement washing the plates of drinking water tanks has its advantages, but the washing must be done with great care, will not stick to paint, and is not durable. It must be watched carefully and renewed frequently.

The Cumberland electrical process appears to be the only way of preserving the interior surfaces of water carrying pipes and circulating systems. It is on the same principle as the alkaline theory. The potential of the water is raised to a point higher than any point of the system by sending a current from an outside source to it from an easily replaced anode. The current must be at a potential high enough to raise that of the water to the proper point and must be kept on continuously. If the potential of the water drops below that of

the metal at any point it will pit or corrode at that point similar to the alkaline solutions. This system will give excellent results when properly installed and properly attended.

The preservation of copper, composition, or iron piping on board ships in the flushing, condenser, and refrigerator circulating systems can be maintained by the Cumberland process if run by some electrical source other than the main power system of the vessel. This process has many drawbacks and requires constant attention. Except by making the piping and tubing of the best and most homogeneous metal obtainable, having it properly made and the finished article properly heat treated and fitted, it seems to be the only practicable plan available. It is sure if properly controlled.

The wrought iron, steel, and other iron manufacturers make many claims for their various materials, claiming maximum durability and resistance to rust. In 30 months of continuous testing of these various products it was interesting to note that in many cases one would show much better than another, but by varying solution, temperature, and treatment they could all be made to give practically similar results.

In waters that are made non-corrosive to iron or steel by alkaline solutions, their metallic contact with copper and other metals lower than iron in the potential series does not start corrosion.

THE ROLLING OF GEARS FROM DROP FORGINGS.

A novel method of manufacturing gears by a rolling process has been developed by the Anderson Rolled Gear Company, Cleveland, and we are indebted for the following description to "The Iron Trade Review."

Drop-forged steel blanks are used, the outside diameters of which are approximately the pitch diameter of the gears to be made. The blanks are not machined before being subjected to the rolling operation, but are rolled after heating, in the condition in which they were received from the forging plant. The blank is rotated against a die roll and is fed in gradually until the proper depth or diameter of the gear is attained. As this is a generating method of forming teeth, one die will roll any diameter of gear of the same pitch and face. The rolling machine now in operation has a capacity for manufacturing spur, herring-bone, and helical gears up to 14in. diam. and sprocket wheels also can be produced.

In operation, the hot blank is fed to chucks, which are then closed by means of a lever. A large taper wedge is next dropped in front of a screw which has a double worm reduction; the hot gear blank then is forced into alignment with the die roll, and a clutch, which actuates a power feed, is thrown in. This causes the chucks to tighten and grip the blank securely. Another power feed carries the chuck and blank toward the die roll. This movement is continued until a stop is reached, when the clutch is thrown out and this power feed is reversed until the blank clears the die roll. The chucks then are opened by power and the gear is removed. The feeds are belt-driven from a line shaft, but the main drive for the machine is actuated by a direct-connected, 30 h.p. high torque motor. After the teeth in the die roll are disengaged from the blank, they are subjected to an air blast, which removes any scale that may become lodged in the die. This operation is followed by an oil spray, which facilitates the separation of the teeth of the gear from the die roll and also imparts a smooth and polished finish to the gear teeth. The die roll is of large diameter and absorbs very little heat from the blank. Its temperature never exceeds 150° Fah.

The whole cycle of forming a gear by this process is completed in from 30 to 60 seconds, depending on the size of gear to be rolled. Drop-forged blanks made from any of the alloy steels, including silico-manganese, can be rolled into gears on this machine. The rolling operation leaves a very slight fin on the ends of the teeth which can be removed readily and some of the metal displaced by the formation of the teeth is extruded in regular corrugations around both sides of the rim of the wheel and is subsequently machined off. As compared with the time required for cutting gears, this 60-second operation effects great economies, in addition to saving a large part of the metal wasted by the gear-cutting process. Each tooth is subjected to a tremendous upsetting or forging pressure which increases the density of the metal and consequently the strength. As each tooth is rolled, the metal is kneaded and worked slowly, without shock, allowing the structure of the metal to change uniformly. The grain of the metal is not cut, but follows the irregular contour of the teeth and the fibres are forced into a pyramid or truss form.

Gears are produced concentric on both pitch and outside diameter within 0·002in to 0·003in and the diameter will vary, plus or minus, 0·0003in on an 8in gear. The increased density of the metal adds to the surface durability, and by using blanks of a fairly high carbon steel, the chilling effect of the die roll will produce a great surface hardness. It is claimed that the tendency to warp in case hardening is a great deal less than with a cut gear, as the structure of the metal at the periphery is changed while hot and there are no internal strains to be relieved.

SEASON-CRACKING OF SHEET BRASS GOODS.

The season-cracking of goods made of sheet brass has always been the most annoying, and at the same time, the most mysterious and perplexing of any of the ills to which brass is subject. The most exasperating difficulty is that which cannot be explained or one for which there appears to be no cause. Season-cracking in brass always occurs in the metal that has been mechanically worked, such as the sheet, wire, rod, or tubing, or goods made from them. Cast metal does not appear to be subject to it.

Brass season-cracks in this way. An article made of brass is put in use and for a time shows no indication of cracking. This time will vary, and may be a few weeks, months, or years, depending upon conditions. It is usually a comparatively long time, a year or more, before the cracking takes place for the reason that if it were to show in a shorter time, it would be very likely to be noticed in the factory or in the dealer's store or warehouse. This lapse of time before the cracking begins to appear renders the problem all the more perplexing. Finally, small cracks appear and they gradually grow larger until, perhaps, the article is completely filled with them and the brass springs apart. Season cracking may be explained in the case of an automobile lamp, which is made of drawn brass sheet, and frequently will show this phenomenon. The lamp, after it has been in use for some time, will begin to crack and gradually spring apart. Various forms of other sheet brass articles are often found cracked in the same manner.

Manufacturers of sheet brass goods which show the season-cracking difficulty are apt to throw the blame upon the maker of the sheet brass; but as far as known, both from investigations and experience, he is wholly guiltless and the cause of the phenomenon cannot be laid at his door. The cause of the cracking, in nearly every instance, is the manufacturer of sheet metal goods. It has already been proved, without a doubt, that the cause of the season-cracking of sheet brass goods is the manner in which they were made. This assertion may appear ridiculous, but it is, nevertheless, quite true. Brass goods are now made, in the majority of instances, by press work and the sheet metal is drawn up to the required shape by this useful machine. It is in the actual drawing operation that the cause of season-cracks exists, and to sift the matter down still finer, in the actual shape of the die and punch.

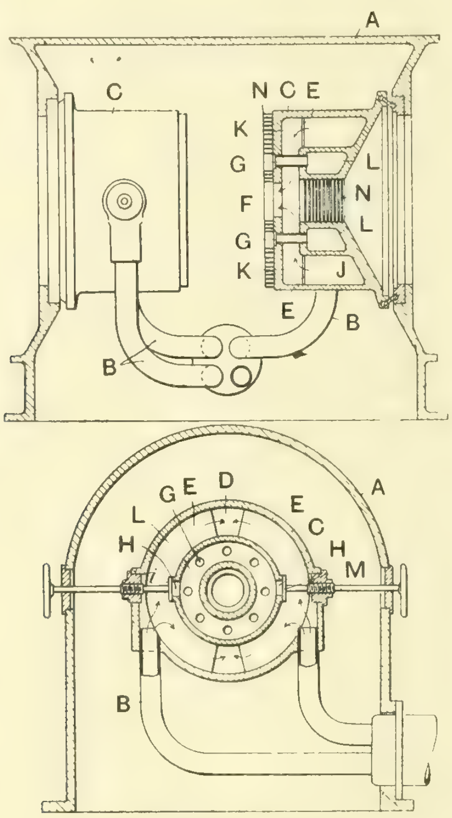
Why the press work is the cause of the season-cracking may be demonstrated as follows: If the sheet brass is merely formed into shape, in the same manner that a paper article would be made, the metal is drawn unevenly and strains then exist in the article. It is these strains, always present, that finally produce the season-cracking. If, however, the punch and die are made so that the metal is stretched evenly all over, the strains in the formed article will be even and the brass will not season-crack. In other words, it is the presence of uneven strains in the sheet brass article that produces the season-cracking, and so many instances have been found in which this has proved to be true, that it seems to leave no doubt about its being the cause of the majority of cases of season-cracking.—"The Brass World."

Tube Postal Railway for London.—The Post Office are contemplating the laying of a tube railway through London for post-office purposes. The line will be six miles long, from Paddington to Whitechapel, and the trains will be run automatically without drivers through a 9ft. tube. The capital cost is estimated at a million pounds.

LJUNGSTRÖMS' STEAM TURBINE.

In steam turbines, especially radial flow turbines with rotors running in opposite directions, the steam is led into hollow chambers which are arranged laterally of the rotors and surround the shafts. Hitherto it has been usual to admit the steam through tubes which open laterally into the chambers, but the steam, when so admitted, causes unequal heating of the chambers when the turbine is heated, for instance at starting, especially when superheated steam is employed, because those parts of the chambers which are situated nearest the point of admission receive the highest temperature. The disadvantage thus arises that the chambers set obliquely whereby the spaces in the labyrinth and shaft packings supported by the chambers are enlarged by the wear of the packing rings and become larger than is necessary for proper working.

To avoid this disadvantage, Messrs. Ljungströms, of Liljeholmen, Stockholm, have designed and patented the construction shown, in which the steam is so distributed in the



Ljungströms' Steam Turbine.

chambers by special distributing members that a uniform heating is obtained. A indicates the turbine casing, B the steam inlet tubes, and C the chambers to which the steam is admitted and which are placed laterally of the turbine rotors (not shown) which are concentrically arranged between the chambers. These chambers support the labyrinth and shaft packings N, which are formed as separate parts, secured to the chambers. The chambers C are divided into two compartments J and K by means of partitions E provided with openings D. The tubes B open into the compartment J, while the compartment K is provided with a central opening F through which the steam can flow into the rotors. The partition E causes the steam to be distributed symmetrically or uniformly in the compartments J and K whereby a uniform heating and thus also uniform expansion of the chambers C is obtained. The steam is distributed substantially as indicated by the arrows. Within the compartment J there is further provided a compartment L communicating with the intermediate rows of blades by means of tubes G. By means of the openings H which are closed by the valves M the compartment L can be brought into communication with compartment J, whereby the high-pressure steam can be introduced into the intermediate rows of blades when the turbine is overloaded.

FUEL ECONOMICS OF THE OIL ENGINE.*

By John A. Secor.

The power-driven vehicle can no longer depend on its present fuel. The demand for gasolene has overtaken production. During the last decade the oil market has been readjusting itself to radically new conditions. This has been brought about by many new applications of oil products for developing heat and power. Crude oil was formerly looked upon simply as the raw material for the production of illuminating and lubricating oils. The invention and perfection of the gasolene motor and its application to the automobile and power boat dates back to the high-speed gasolene engine of Gottlieb Daimler. The introduction of the Daimler motor opened up an entirely new market for the lighter oils, gasolene and naphtha, which market developed within the short period of 10 years into larger proportions than the most optimistic oil men ever dreamed of. Under these conditions the inexorable law of supply and demand brought about a price level for the volatile distillates far in excess of former values.

For nearly half a century price advances were extremely moderate; the fluctuating market quotations of gasolene were ordinarily within narrow limits. But last year an unparalleled increase took place. United States Government reports show that the advancing price of gasolene is due solely to inevasible laws of supply and demand. No corporation or combination of corporations is responsible for the fact that demand has overtaken production, and that further increases in prices are now impending. American gasolenes and naphthas were formerly obtained solely from high-grade paraffin crude oils of Pennsylvania and Ohio. These are the most valuable oils in the world. Highest-grade Pennsylvania crude now actually brings the same price as refined kerosene in bulk. But unfortunately Pennsylvania production has fallen from 33,000,000 bbl. in 1891 to about 9,000,000 bbl. at the present time. Ohio production has decreased from 24,000,000 bbl. in 1896 to less than 9,000,000 bbl. during the year last past. The zenith of production of Indiana was in 1894—over 11,000,000 bbl. The present yield shows a shrinkage of nearly 90 per cent. from maximum. The United States Geological Survey states that the general decline in production "would doubtless have been much greater but for the effort to apply laws of supply and demand by increases of prices. Prices advanced so greatly during the year as to stimulate drilling, even in the old New York and Pennsylvania pools, and so checked the decline. Formerly this plan has not been so successful. In the mid-continent field also it checked the decline, so that the product will come within 4,000,000 bbl. of the maximum output."

In Canada production has fallen off one-third from the highest of five years ago. The only new field in sight is at Tampico, in Mexico, which has grown from nothing three years ago to 6,000,000 bbl. in 1912. About the only home fields not showing decreased output are in California and Oklahoma. Three-fifths of the total yield now comes from these two States. And even the increased output of Oklahoma was insufficient to prevent a continuous reduction of stock on hand in 1912. Ninety per cent. of the entire output of more than 220,000,000 bbl. was crude oils, which yield a very low percentage of gasolene.

In order to obtain a single gallon of gasolene from refinable California petroleum, it is necessary to produce as by-products 9 galls. of kerosene and 30 galls. of residual oils. Notwithstanding the steadily increasing output of Western oil, the price of gasolene on the Coast continues to advance. Large shipments of Texas oil formerly came to the Atlantic seaboard in tank steamers, but these have decreased as the Texas oil yield is now less than one-third the 1905 output. In view of the Texas shrinkage it is obvious that the opening of the Panama Canal will furnish a large Eastern market for California oil, but it is equally obvious that under existing conditions that will not materially affect the gasolene situation.

There are five different methods of increasing the normal visible supply of gasolene. One is importation. The Standard Oil Company has imported some Russian naphtha, but Russia has no more to spare, as her own oil output is diminish-

* Abstract of paper read before the American Society of Automobile Engineers.

ing to such an extent as to increase the price 100 per cent. in the last two years, and to warrant the Russian Government in the promotion of alcohol production. The Shell Oil Company, of England, has also shipped some gasolene from Borneo to Canada, but the total quantity available abroad is insufficient for home demands. America is still exporting gasolene to foreign markets at the rate of 15,000,000 galls. to 20,000,000 galls. per month.

Another and more promising means of obtaining gasolene is by increasing the total yield of American crude oils. A yearly production of 300,000,000 bbl. in the United States is probably being approached faster than even oil men generally believe. But the largest increase in the production of gasolene in one year has never been more than 5 per cent., while the production of power-driven vehicles will in all probability represent an increase this year of around 100 per cent. Furthermore, as already shown, the supply of gasolene yielding crude oils is rapidly decreasing; the increased crude output will consist of Oklahoma and California asphalte oils, having insufficient gasolene for existing requirements.

The third means of supplementing the gasolene supply is the production of gasolene from kerosene. Chemists have known for some time that it is entirely feasible to extract gasolene from the chemically complex kerosene, as well as from coal, coal tar, and even wood. It is simply a question of cost, and of the profitable disposal of resultant by-products. Gasolene is now being made from kerosene, and a further increase in price will stimulate an increased output.

A fourth source of gasolene supply is its manufacture from natural gas by compression, and its subsequent condensation to a liquid form. It is claimed that this process produced 13,000 galls. in 1910, which was increased to 50,000 galls. in 1911 and about twice as much in 1912. Some of the richer gases produce as much as 8 galls. per 1,000 cub. ft., but the average is from 3 galls. to 5½ galls. By triple and quadruple compression up to pressures as high as 400lbs., very light liquids as high as 85° Baumé are produced, these being slightly more stable than the products of fractional distillation.

The fifth and last means of increasing the available gasolene supply is by lowering the Baumé gravity. It is probable that the specific gravity of commercial gasolene will be dropped another notch by next summer. Much of the liquefied-gas gasolene is used for blending with heavier distillates, and naturally other than gravity tests are required to determine the characteristics of such blended gasolenes.

With the exception of importation, the various methods of augmenting the available quantity of gasolene are now in active operation; and every increase in price is a stimulus to additional output.

This brief review of market conditions shows that the problem of an adequate supply greatly overshadows the collateral problem of the increasing cost of gasolene. Fortunately we have two alternative liquid fuels immediately obtainable. Alcohol and kerosene oil offer an ample supply of satisfactory fuel to the power-driven vehicle. We need not discuss alcohol at this time, further than to point out that special engines with appropriate compression are required, as gasolene engines are not adapted to alcohol. Predictions heretofore made in regard to denatured alcohol as a fuel have not yet materialised.

But the one best fuel is oil. Oil combines more advantages than any other. It is the fuel of the future as well as of to-day. In comparison with gasolene or alcohol it is much cheaper; safe; better adapted to shipment; more uniform in quality; more highly concentrated; more powerful; and above all, more abundant in all localities. Even in the far-distant future, when the crude oil output will have fallen below the world's demand for liquid fuel, a practically unlimited source of oil will be the great oil-bearing shales which cannot be worked profitably at the present low price of kerosene.

After many years of observation and experience, I am convinced that as a medium for generating power for transportation on land or water, mineral oil or kerosene is the most valuable general-purpose fuel known to commerce. This statement is made in full recognition of the fact that the oil engine has always had less commercial popularity than either the gas or gasolene engine. In former days the oil engine was heavily handicapped by the high price of both crude and refined oil. But time has completely reversed the market relations of gasolene and oil. Oil production is in excess of consumption. Kerosene is now the by-product and quoted at 60 per cent. less than gasolene.

Of several hundred experimental or commercial oil engines made since the days of Brayton in 1876, nearly all were successful within certain limitations. The detracting feature in these engines is the lack of flexibility, which also characterises the common kerosene lamp. It may be conceded that gasolene is by no means a flexible fuel in comparison with gas, but it is much superior to kerosene as heretofore used for illumination in lamps, or for power in combustion engines. There is no difficulty in operating a kerosene lamp properly adjusted to constant conditions. And there is not the slightest difficulty in using oil fuel in any ordinary gasolene automobile when fuel mixture, compression, temperature, atmospheric humidity, power output, engine speed, spark intensity and position, and fuel density are correct and absolutely constant. Under ordinary working conditions an ordinary engine with practically any good gasolene carburetter can use kerosene if kept at medium speeds.

A Maxwell car was thus taken from New York to Boston, operating entirely on kerosene except for starting. But the lack of adequate flexibility becomes increasingly apparent as the speed and power are reduced. If slowed down the car will not "pick up." One of the chief differences in the operation of stationary and automobile motors is that the former are generally governed on the hit-and-miss principle, whereas the latter are controlled by means of the throttle. Hit-and-miss governing is a great aid in the successful use of kerosene, because every charge taken in by the engine is a full charge and hence always equally proportioned and also compressed to the same pressure. Therefore with a hit-and-miss governor it is only necessary to get carburettion right for one particular set of conditions. With throttle control the problem is much more complex. Nevertheless, the admitted crudity of hit-and-miss regulation precludes the necessity of serious discussion of it in connection with the modern oil engine.

Most of the oil engines which have reached the commercial stage may be classified under four general types. These typical engines include: (1) The Brayton: Constant flame type. (2) The Hornsby-Akroyd: Vaporising type. (3) The Diesel: High compression type. (4) The Secor: Unitary control type.

The first of these, the Brayton, was exhibited at the Centennial Exhibition in Philadelphia in 1876. A salient feature of the engine was ignition by means of a constant flame within the combustion chamber. Brayton's objective was simply to produce an engine which could burn oil. Its performance was creditable for that early day. It was the predecessor of the Otto gas engine of 1878 and all gasolene engines.

The second of the typical oil engines, the Hornsby-Akroyd, had for its objective easy starting and simplicity of operation. It was very successful in both respects. Many previous oil engines, such as the Priestman, were sometimes exceedingly difficult to start and operate.

The third of the typical engines is the Diesel, in which the objective is thermal efficiency. The engine is an unqualified success in achieving the desired end. Its indicated efficiency is 48 per cent., which exceeds that of any other commercial heat engine of any type. This efficiency is partly offset, however, by an abnormally low mechanical efficiency of 70 to 72 per cent., which reduces the brake efficiency to a maximum of 35 per cent. when the engine is operating under the best conditions. It is about 17 years since the Diesel was first introduced.

The fourth typical oil engine, the Secor, embodies a fuel method which differs radically from that of other oil engines, in both principle and in operation.

It is recognised that oil differs from gasolene in that it is: (1) Non volatile. (2) Contains more B.T.U. per gallon and is heavier. (For example, 65 gasolene weighs 6lbs. per gallon; kerosene, about 6¾lbs.; 37 distillate, 7lbs.; and 31 crude, 7¼lbs.) (3) Oil is practically incombustible at ordinary temperatures. (4) Its range of combustible-mixture proportions is much narrower than that of gasolene. (5) The physical con-

ditions for complete combustion are more exacting than in the case of the volatile liquid fuels or gases.

It resembles gasolene in that it is composed of complex chemical constituents with widely varying temperatures of vaporisation. The fuel mixtures in a throttling-governed engine should vary in proportions in consonance with the variations in compression. "Constant mixtures" are detrimental in a gasolene engine and utterly impracticable in an oil engine.

In view of the chemical complexity of oil fuel, and its lack of any fixed point of vaporisation, and of the narrow range of working fuel mixture proportions, the only possible solution of the oil-engine problem is to concentrate the control of all functional operation under one multiple-unit governor, which shall regulate simultaneously all independent agencies to suit the existing conditions. The multiple-unit governor regulates: (*a*) Fuel mixing proportions, supplying weaker mixtures for higher compressions and relatively stronger mixtures for low compressions and power output. (*b*) Quantity of fuel mixture. The quantity of fuel mixture is also controlled by the governor, which thereby determines compression, mean effective pressure, power output, and revolutions per minute, as in gas engines. (*c*) Internal temperatures during compression, ignition, and combustion are controlled by adding variable quantities of finely-atomised water to the fuel mixture, the quantity of water being varied in proportion to the variation of temperature within the combustion chamber. (*d*) Ignition timing. In engines with variable speed the governor may advance or retard the point of ignition in consonance with variations in speed of engine. This is important in all cases where there is extreme variation in engine speed. (*e*) Speed control. (*f*) The use of gasolene for starting, the fuel supply being operatively connected so that as the engine speed accelerates in starting the gasolene supply is steadily lessened.

In view of what is claimed for the Secor-Higgins carburetter and what it has already accomplished, is it adapted for the power car and motor truck? I must say, frankly, that I do not know. We have had no time to take up experimental or research work along automobile lines. But we think it may be safely predicted that the time is at hand when gasolene will no longer be the sole fuel, or even the leading fuel for the automobile. We think it also safe to predict that the coming oil automobile engine will demonstrate the fact that one definite proportion of fuel to air does not give the best results under all circumstances, but that the ideal mixture must vary with every change in working conditions. Also, that the heated carburetter is a delusion and utterly impracticable. And finally, in view of the complexity of oil fuel and the changes in working conditions, that the principle of controlling all working factors in unison is an absolute necessity in a flexible automobile motor.

Electricity in Mines.—A description of the electric plant at work at the Cannock Chase Colliery was given at a recent meeting of the Birmingham branch of the Institution of Mining Engineers by Mr. S. F. Sopwith. Seeing that the effect of additional legislation was to increase the cost of production, it had become essential, Mr. Sopwith said, that modern methods should be introduced into the older collieries, if the all too narrow margin which normally existed between costs and selling prices was not to be reduced to vanishing point. The aim of the colliery manager of to-day was not so much to reduce costs as to maintain them at their present level, despite the ever-increasing burdens which the exigencies of the times put upon him. It was on this account that the company decided to adopt electricity, with a view to reducing colliery consumption and providing a means of transmitting power underground for haulage and other purposes. The total cost of the entire installation was £21,259. By the adoption of the scheme, said Mr. Sopwith, the colliery consumption had been reduced by at least $1\frac{1}{4}$ per cent., or 6,875 tons. About 25 horses had been dispensed with underground, and a great reduction in labour had resulted from the substitution of mechanical for horse haulage. The current was available underground for further extensions in the way of auxiliary haulage, coal cutting, &c., and for lighting up important stations, which, if not actually economical, was more convenient and safer. He computed that the total saving represented about $18\frac{1}{2}$ per cent. interest on the capital outlay.

INDUSTRIAL AND TRADE NOTES.

The White Star Liner "Britannic."—According to a Belfast correspondent, the following are the dimensions of the "Britannic," now being built by Harland & Wolff for the White Star Line: Length, 887ft. 9in.; breadth, 94ft. 6in.; gross tonnage, about 51,000. It is expected that she will be launched next November or December. Allowing seven months for fitting out, she should thus go her maiden voyage about August, 1914.

New Locomotive Workshops at Victoria.—The Victorian Railways Commissioners have, we learn, decided to erect locomotive workshops at Ballarat and Bendigo, and the necessary detailed plans and estimates are now being expedited, in order that tenders for the preparation of the site may be invited without delay. The equipment to be provided at the new workshops will be of the latest type, and will include all classes of machine tools, and other engineering appliances. The approximate cost of the equipment at each depôt will be about £28,000.

Proposed Rebate in the Iron Tube Trade.—A meeting of the All England Tube Trade, Associated, was held on Monday last to receive a committee of association buyers with a rebates scheme proposal. At present the Tube Association allow a graduated system of discounts of 5 to $7\frac{1}{2}$ per cent. The associated buyers proposed a new system of rebates, having a minimum of $2\frac{1}{2}$ to 5 per cent., and a maximum of 10 to $12\frac{1}{2}$ per cent. The new scheme would be identical with that recently prevailing in the light castings trade. The Tube Association promised favourable consideration of the proposition.

Large Power Project.—A project is on foot for developing 300,000 electrical horse power at Big Eddy, a point three miles above The Dalles, on the Columbia River. At this point the river runs through a narrow gorge which could be closed by a dam 300ft. long and 180ft. above its foundations, and the construction of a canal 300ft. wide, 20ft. deep, and $1\frac{1}{2}$ miles in length. The head of water is 73ft. at low water and 42ft. at high water, and the mean flow of the river throughout the year is 235,000 cub. ft. per second. The hydro-electric units would be each of 32,000 h.p., and the total cost of the scheme would be about £4,600,000.

White Star Line and Manchester.—The White Star Line have arranged to establish a regular service of cargo steamers between Manchester and New York, both outwards and homewards. The service will be inaugurated by the steamer "Memphian," sailing from Manchester June 21st, to be followed by the "Cevic," scheduled to sail July 12th, with three-weekly sailings thereafter. The White Star Line have not previously had any service from Manchester, and there has been no direct regular service by any line from Manchester to New York, although direct sailings from New York to Manchester have been maintained.

Transatlantic Wireless Stations.—The Marconi Wireless Company are erecting two of the largest and most powerful wireless stations in the world. One of these has been commenced in Wales, and the construction of the other is about to be begun at Belmar, New Jersey. Each will consist of 13 masts, 400ft. high. The two stations will be worked in connection with each other, and each will send and receive messages across the Atlantic at the same time. They are intended as links in the chain by which the company will girdle the world. Other equally large and powerful stations are to be constructed on the Pacific coast, at Honolulu, and in Japan.

Launch of a Diesel Motor Ship.—A twin-screw motor vessel, built to the order of Messrs. Lane & Macandrew, London, was launched on the 24th ult. by the Caledon Shipbuilding and Engineering Company, Dundee. The vessel, which was named "Sebastian," is of the following dimensions: Length over all, 321ft. 3in.; breadth moulded, 45ft.; depth moulded, 26ft. 3in., and she is of about 3,400 tons gross. The vessel has been designed for the carriage of oil in bulk, and is divided into some 28 oil tight compartments by longitudinal and transverse bulk heads. The propelling machinery will consist of two sets of Diesel oil engines, which are being constructed by the Aktiebolaget Diesel Motoren, Stockholm.

Coal Output per Individual.—According to the statistics of coal production just issued, the average production of coal per person employed in Northumberland mines in 1911 was 252 tons, and for the past year it fell to 226 tons. For Durham the prior average of 263 tons fell to 237 tons last year. These reductions are accounted for by the coal strike. The highest average output per person last year was for Nottingham—about 282 tons—whilst for the South Wales coalfield it was 222 tons, though the latter does not show a heavy fall, as in the previous year local strikes affected the miners' yield. For the whole of the kingdom the average output per person employed at the collieries was 241 tons, one of the lowest average yields of recent years.

Wages in Shipyards. A conference was held at Edinburgh on the 22nd ult. between the masters and men in the shipbuilding trade on the subject of a demand for an increase of 5 per cent. on piece prices, and a shilling per week on time rates. The parties were at variance as to whether an advance is justified by the present state of the industry, and the conference failed to arrive at a satisfactory conclusion. It is understood that the Standing Committee of the shipyard trades will place the subject fully before the members of the 11 unions which are parties to the National Agreement, and ask for a vote on the question of taking steps to enforce the advance. In that case a good deal will depend on what recommendation—if any—the committee may give to the men. The process of voting will require from two to three weeks, and it is likely that after the result is known negotiations with the employers will be reopened.

Trade Union Progress.—The report of the Chief Registrar on trade unions issued on Saturday last does not deal with matters later than 1911. The report states that there remained upon the register at the end of 1911 680 trade unions, of which 570 were registered in England and Wales, 36 in Scotland, and 74 in Ireland. The majority of the unions showing heavy increases in membership were connected with the transport trades and general labour. The mining, conveyance, and engineering groups include more than 60 per cent. of the membership of trade unions. At the end of 1911 the number of unions was 680, with a membership of 2,378,957. The total funds of registered trade unions at December 31st, 1911, together with the increase during the year 1911, amounted to £6,326,712, an increase of £454,872, or 7·75 per cent. Two groups—mining and quarrying, and engineering—held more than half the total funds of registered trade unions.

A Large Crane.—The Deutsche Maschinenfabrik A.G., Duisburg, have just put into service at the Hamburg shipyard of Messrs. Blohm & Voss what is described as the largest crane in the world. It is being employed in the fitting out of the 56,000 ton sister ship of the "Imperator," and it has a maximum lifting capacity of 250 tons. The forward arm of the jib has a total length of over 315ft. When the jib is completely raised, the point is at a height of 330ft. above water level. The crane is electrically driven, and has two independent lifting appliances. A crab can lift the maximum load of 250 tons at an outreach of 113ft., and 110 tons at 175ft., and there is a revolving travelling crane of 20 tons' lifting capacity. This auxiliary crane can lift a load of 10 tons at a distance of 240ft. from the turning centre of the crane. With this the working field is about 470ft. diam., so that practically 182,920 sq. ft. can be served. Only two men are required for working the crane.

British Trade with China.—A meeting of manufacturers interested in the engineering trades was held at Sheffield on the 24th ult. to hear explained the objects of the British Engineers' Association. Mr. Douglas Vickers, who presided, explained that the association, which was formed last year and has 112 members, representing an aggregate capital of over 44 millions, existed for the purpose of exploiting the Chinese market in the interests of British engineers. Germans and Americans, he pointed out, were offering facilities for the study of their language to the Chinese, and were also introducing their machinery into China. It was desirable that our own Government should assist British firms, and they could do it by furthering the education of the Chinese in English methods. They wished further to induce the Government to protect English interests by inserting clauses in loans which should specify, as was done notably by France, that the capital should be spent on English products.

Launch of an Isherwood Oil Tanker.—The Greenock and Grangemouth Dockyard Company, Greenock, launched a few days ago the second oil steamer, "Uncas," built by them on the Isherwood system. The vessel is intended for the carriage of petroleum in bulk under special survey. She is the second oil steamer built on this system to be launched on the Clyde. The vessel has been built to the order of the Tank Storage and Carriage Company, London. She will carry a deadweight of 7,200 tons on a light draught, and her dimensions are: Length, 380ft.; breadth, 51ft. 9in.; depth, 29ft. 8in. She has been designed to carry all classes of oil from the lightest to the heaviest grades. She has 16 oil-tight compartments and 10 summer tanks for carrying light grades of oil, so as to ensure the full deadweight being carried at all times. There is a complete installation of pumping machinery, which can discharge the full cargo in 20 hours. Triple-expansion engines are being supplied by Messrs. Rankin & Blackmore, Greenock.

German Copper Refining Industry.—According to the Board of Trade Journal, the quantity of copper ore mined in Germany in 1911 amounted to 868,600 tons, as compared with 920,600 tons in 1910; the average of pure copper in 1910 was 2·51 per cent. Practically the whole of the ore is produced by one company. The greater portion of the ore in Germany is first converted into "matte," which is then reduced to "blister copper" and finally refined in a reverberatory furnace. By this process 32,331 tons of refined copper were produced from 865,090 tons of copper ore and 2,204 tons of "matte" in 1910 as compared with 29,787 tons of refined copper from 775,716 tons of ore and 2,076 tons of "matte" in 1909. In addition to the above 5,151 tons of electrolytic copper and 4,140 tons of cement copper (residue recovered from roasted pyrites) were obtained in Germany in 1910 as compared with 4,178 tons of electrolytic copper and 3,423 tons of cement copper in 1909.

Private Shipbuilding in Germany in 1912.—During the past year there were, according to the "Borsen Zeitung," laid down for German account in German private yards 41 warships with a total gross register tonnage (capacity) of 165,420 tons, 1,010 merchant vessels of 1,224,979 register tons gross, and 113 river vessels totalling 14,089 register tons. Of the foregoing vessels the following were completed: 21 war vessels aggregating 51,100 register tons (capacity) gross, 659 merchant vessels of 383,090 register tons gross, and 71 river vessels with a gross register tonnage of 8,500 tons. For foreign account there were being built four war vessels with a total gross capacity of 11,112 register tons, 170 merchant vessels with a total of 61,489 register tons, and 63 river vessels of 5,642 gross register tonnage. Of the foregoing there were completed two war vessels having 962 register tons, 124 merchant vessels having 31,238 register tons, and 50 river vessels of 5,148 register tons. During the same period there were being built for German account in foreign yards 203 merchant vessels of 85,676 register tons gross and 13 river vessels (steamers) of 1,961 register tons gross. Of these there were completed 150 merchant vessels of 71,689 register tons, as well as 11 river steamers of 1,801 register tons gross.

METAL QUOTATIONS.

TUESDAY, APRIL 29TH.

Aluminium ingot	95/- per cwt.
" wire, according to sizes, &c. ......from	112/- "
" sheets " " ...... "	120/- "
Antimony ....£31/-/- to	£33/-/- per ton.
Brass, rolled	8d. per lb.
" tubes (brazed)	10½d. "
" " (solid drawn)	9d. "
" " wire	8⅞d. "
Copper, Standard	£67/10/- per ton.
Iron, Cleveland	67/- "
" Scotch	73/- "
Lead, English	£18/5/- "
" Foreign (soft)	£17/17/6 "
Mica (in original cases), small	6d. to 3/- per lb.
" " " medium	3/6 to 6/- "
" " " large	7/6 to 11/- "
Quicksilver	£7/10/- per bottle.
Silver	27 1/16d. per oz.
Spelter	£25/7/6 per ton.
Tin, block	£227/-/- "
Tin plates	14/3 "
Zinc sheets (Silesian)	£28/10/- "
" (Stettin; Vieille Montagne)	£28/12/6 "

The Institution of Electrical Engineers: Admission as Student.—The Institution does not hold a qualifying examination for admission as student. On and after June 1st, 1913, all candidates for election to the class of students will be required to have one of the following qualifications: (1) The matriculation examination of any university in the British Empire, or the responsions examination of the University of Oxford; or the previous examination of the University of Cambridge. (2) The studentship examination of the Institution of Civil Engineers. (3) The school-leaving examination for the Scottish Education Department. (4) The naval cadet passing-out examination. (5) The entrance examinations for Woolwich and Sandhurst. (6) The school examination (for school-leaving certificate) or the senior school examination of the University of London. (7) The Oxford or Cambridge local examination. (A senior certificate provided it covers English and elementary mathematics.) (8) The Oxford and Cambridge higher certificate (provided it covers English and elementary mathematics). (9) The abiturienten examination of any German or Austrian secondary school, or the corresponding examination of similar schools in other countries. (10) The certificate of any other educational authority which may be recognised by the Council of the Institution as equivalent for the purpose of admission to the class of students.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Airships and aeroplanes. Wilson. 483.
Preventing excessive friction between rotary valves and their seats. Soc. Anon. des Etablissements Malicet & Blin. 5547.
Apparatus for the automatic and continuous analysis and indication of gases. Boulton. 5601.
Extraction of copper from sulphide ores. Hybinette. 5806.
Process for the production of steam for gas generators. Främbs, and Bender & Främbs Ges. 5852.
Instruments for measuring the velocity of flow or the pressure of air, steam, and gas. Lyall & Davis. 8015.
Heat interchangers. Holden, Tiddeman, & Russell. 8023.
Steam traps. Lawson. 8090.
Oil filters. Maranville. 8185.
Revolution-direction indicators and recorders. Flaman. 8231.
Method of forming briquettes of fine granular materials for metallurgical purposes. Boehm. 8246.
Treatment of sulphurous ores. Fusina. 8426.
Carburetters for internal-combustion engines. Tampier. 8436.
Pyrometers. Rogers. 8486.
Ventilating fans. Trautmann & Copping. 8514.
Variable-speed friction gearing. Ottino. 8597.
Automatic coupling for railway vehicles. Murphy. 8648.
Balancing multi-cylinder engines. Imray. 8693.
Railway signalling. Tarrant. 8811.
Apparatus for starting multiple-cylinder internal combustion motors. Weckerlein & Stocker. 8986.
Fluid pressure motors of the rotary type. Eisner. 9282.
Pumps. British Thomson-Houston Company. 10881.
Internal-combustion engines. Zoelly. 10991.
Adjustable bearing. Smith. 11333.
Carburetters. Doudney. 11577.
Turbines. Hutson & Ford. 11601.
Friction-driven variable speed gear. Hughes & Manderson Lobb. 12331.
Rotary engines. Roberts. 12394.
Change speed gears. Schweinfurter Pracisions Kugel Lagerwerke Fichtel & Sachs. 12702.
Sight feed lubricators for steam engines. Bebbington. 12822.
Carburetters for internal combustion engines. Baron Stalbridge. 12851.
Centrifugal governors. Belliss & Morcom, Ltd., & Walshe. 12926.
Thrust bearings. Egbert. 13279.
Process for casting steel in several layers. Imray. 14234.
Air-cooled internal-combustion engines. Cohen. 14479.
Wrenches. Willis. 14925.
Device for indicating at a distance the level of the liquid contained in a tank. La Force. 15160.
Combination aeroplane and dirigible machine. Christitch. 15533.
Manufacture of alloys. Naylor & Hutton. 15690.
Machines for cutting metal bars. Clifton & Baird, Ltd., and Clifton. 15822.
Transmission mechanism for motor-vehicles. Lake. 16066.
Change-speed gearing. Fazan. 16069.
Automatic valves of disc form. Alley & McGregor. 16203.
Bearings. Wallace. 16294.
Preparatory refining furnaces adapted to be supplied direct from the blastfurnace in the manufacture of steel. Bernhardt. 17543.
Wrenches. Maher, Pfaff, Campbell, & Terry. 17575.
Continuously operating annealing furnaces for metals. Kugel. 18082.
Guards for machine tools. Williams & Field. 18105.
Open hearth furnaces adapted for use with blastfurnace gas. Poetter Ges. 18148.
Manufacture of boiler stays. Huntington & Preston. 18574.
Construction of vaneless turbines. O'Reilley. 18832.
Coupling or clutching apparatus. Van Daalen & Schreiber. 18991.
Steam boilers. Kestner. 21547.
Centrifugal liquid pumps. Woodroffe & Hodgson. 21965.
Nut locks. Patterson, Oliger, Simms, & Pree. 22822.
Air compressors. Francois. 23840.
Aeroplanes. Coanda. 26911.
Stop valves. Koenig. 27603.
Cable ways. Bleichert & Co. 29586.

1913.

Apparatus for purifying, cooling, and washing gases. Theisen. 1382.
Sectional boilers. Oscar R. Mehlhorn. 1640.
Valve gear for two stroke cycle internal-combustion engines. Fried. Krupp Akt. Ges. Germaniawerft. 2132.
Variable speed gears. Adolph Saurer. 2280.
Furnace back bridges. Gould. 2654.
Railway rail joints. Moore. 3197.
Bearing brasses. Ransomes, Sims, & Jefferies, Ltd., and Rignall. 1270.
Cylinder heads for internal combustion engines. Hesselman. 4555.
Tapping mechanism for multiple spindle metal working machines. Smith. 5932.

ELECTRICAL, 1911.

Electric transmission of power. Van Daalen & Schreiber. 24122.

1912.

Telegraph systems. Harrison, Moore, & Savin. 5655.
Electrical engine or machinery direction and counting tell tale. Clarke, and Chadburn's (Ship) Telegraph Company. 5692.
Thermo electric heating and cooling body. Altenkirch & Gehlhoff. 8050.
Arrangement for starting and regulating direct current electric motors. Cumont. 8108.
Electric arc lamps. Ogilvy Webb, White, & Reinecke. 8232.
Manufacture of drawn tungsten wires. Fischer. 9981.
Pre payment electricity meters. Turner. 13647.
Conductor rails for electric railways. Merz & Redman. 13801.
Machines for manufacturing electric incandescent lamps. British Thomson Houston Company. 14962.
Electric meters. Allgemeine Elektricitats Ges. 16358.
Electrodes for arc lamps. British Thomson Houston Company. 16707.
Electric cut-out switches. Kovacs. 17635.
Wireless system to selectively call up stations. Jamieson. 19014.
Electrical switches. Horton. 21102.
Regulators for electric train lighting systems. Kennedy. 21157.
Dynamos and motors. Price. 21932.
Sparking plugs. Deligny. 22530.
Device for automatically stopping electric hoists. British Thomson-Houston Company. 26681.
Armature for direct-current watt-hour electricity meters. Moul. 27246.

1913.

Current rectifying apparatus. Conrad. 622.
Sparking plugs. Siemens & Halske Akt.-Ges. 1064.
Telephone systems. Rickets. 2397.

Fatal Crane Accident.—By the collapse of a crane on a building site in High Holborn on the 24th ult. one man was killed and another injured. Iron girders weighing two tons were being lowered into position when, it is stated, one of the chains which held the crane in position 113ft. above the ground snapped.

Mining Institute of Scotland.—The 36th annual general meeting of this institute was recently held at Glasgow. The following office-bearers were appointed for the ensuing session: President, Mr. James Hamilton; vice-presidents, Messrs. D. M. Mowat, Douglas Jackson, W. Walker, Wallace Thorneycroft, James Barrowman, and Jas. Bain. Prof. Daniel Burns submitted the report of a committee who had been appointed to carry out a series of experiments with a view to testing the accuracy of a loop device described by Mr. Henry Briggs, of the Heriot-Watt College, Edinburgh, as useful in detecting small percentages of fire-damp and black damp in the mine. Prof. Burns explained that tests with the loop had been carried out both in the Royal Technical College, Glasgow, and Bothwell Castle No. 5 pit. The inference from the experiments which had been made suggested this, that as a practical appliance the Briggs loop appeared to the committee to be inferior to the lowered flame for gas testing purposes in the mine, and further, in order to obtain results with it a much more careful process of manipulation was required than was necessary with the ordinary lamp. It was decided to adjourn the report for further consideration. Mr. Henry Rowan read a paper on "Underground Fires." Although a great deal had been written and said on the subject, investigators were, he remarked, still very much in the dark regarding the cause for the spontaneous heating and firing of underground workings. Various proposals had been put forward as to the best means of dealing with active underground fires, but he agreed with those who held the view that each gob fire must be taken on its own merits. He (Mr. Rowan) was of opinion that if some method of hydraulic stowing were adopted a great quantity of coal could be recovered from those areas which had been abandoned in consequence of fire.

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Edited by
WILLIAM H. FOWLER
Wh. Sc., M.Inst C.E.

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The Smoke Abatement Bill.

A RATHER drastic measure for dealing with the smoke nuisance of manufacturing towns was introduced by Mr. Gordon Harvey to the House of Commons last week. The Bill, which is promoted by the Smoke Abatement League of Great Britain, of which Mr. Harvey is president, deals only with the smoke of boilers and manufacturing processes, and makes no provision for the control of domestic fires, but its clauses are stringent and far-reaching, since they apply not merely to works, but also to any vessel in territorial waters and to smoke, whether black or any other colour, as well as to the emission of ash or gritty particles. The maximum penalty for a first conviction is £5, but, as this may be doubled for each subsequent conviction, the fine may obviously assume very serious dimensions. Exemptions are only to be granted in the case of metallurgical and pottery furnaces, and even then only as a result of individual application to the Local Government Board, who, if the Bill passes, are to be empowered to establish Joint Boards of neighbouring authorities on the lines of those which now act to prevent river pollution. For carrying out the provisions of the proposed measure, they are also to have the appointment of inspectors, pretty much on the lines of those now appointed under the Alkali Acts. Existing authorities are only to be endowed with powers when the Local Government Board is satisfied their duties under the Bill are satisfactorily carried out.

With the amiable and ostensible objects of the Smoke Abatement League, as expressed in the Bill, few people will disagree, but boiler owners and manufacturers will nevertheless need to scan its provisions carefully, for drastic powers of prosecution, when vested in Government officials, can be used in a very harassing manner, and the attitude of some of the enthusiasts associated with the League towards the smoke question does not inspire confidence in their ability to treat some aspects of it fairly, or impel a belief that they always understand the difficulties of securing constant, and at the same

time economical, smokeless combustion. The chemical reactions of a boiler furnace are well understood, and, as those who are familiar with them know, the margin of economic and efficient working, free from smoke, is in many cases rather narrow, no matter how well the furnace may be equipped. Demands for steam are not always uniform. In some industries it fluctuates greatly, and, without unreasonable capital expenditure on boiler plant, it is almost impossible to avoid periods of stress, while the best mechanical contrivances are liable to derangement, and require periodical adjustment. Where stoppages are frequent, it is not difficult to effect these, but when the exigencies of manufacture require continuous working, the case is different, and only those with an intimate knowledge of the local conditions can appreciate the difficulties boiler attendants have to contend with. We do not hold a brief for the emission of smoke or grits wherever they can be prevented, as we readily admit in many cases they can be by the exercise of reasonable care. But, on the other hand, a wide experience of the conditions under which many industries have to be conducted, and of the harass which may be inflicted on those engaged in them by officious smoke inspectors, convinces us that "prosecution" may easily become "persecution," and that any proposal to extend the arbitrary powers of officials of this kind should not be allowed without careful scrutiny and adequate safeguards against abuse.

Cast-iron Boiler Fittings.

WE have frequently called attention to the danger of using cast-iron for steam pipes and valve chests of boilers working at high pressure. Failures in connection with them form the subject of a considerable percentage of the enquiries held under the Boiler Explosions Act. The material is objectionable, not only on account of its low tensile strength, but also because it is difficult to secure uniformity of thickness under the ordinary conditions of manufacture, and further still because of its lack of ductility. A casting may appear quite sound and safely withstand a hydraulic test, and yet be subject to internal stresses that make it a constant menace to safety when exposed to the racking temperature movements in a steam pipe connection. For this reason, the use of cast iron is deprecated by all boiler engineers except in special cases, and for very low pressures. A formal investigation concluded by the Board of Trade at Liverpool on the 29th ult. into the circumstances attending the deaths of six men who were scalded to death on board the steamship "City of Lincoln" on her first voyage, through the sudden bursting of a cast-iron steam stop valve chest, serves to emphasize the wisdom of this attitude, especially on board ship, where, owing to the confined space, any sudden rush of steam is liable to produce fatal consequences to the engine-room staff, and may in bad weather jeopardise the safety of the ship. Cast-iron valve chests have no doubt certain commercial advantages owing to the facility and expedition with which they can be obtained, but their drawbacks are so serious that only exceptional circumstances and the exercise of the utmost care in manufacture and testing can justify their adoption.

Birmingham Foundrymen's Association.—The annual meeting of the Birmingham Foundrymen's Association was held on Saturday last, when the following elections were made: President Mr. C. Heggie, senior vice-president Mr. H. Pemberton, junior vice-president Mr. D. Dalrymple, and hon. secretary Mr. Grinley. A vote of thanks was passed to Mr. G. Hailstone, for some time secretary, who is retiring owing to the work in connection with the Carnegie Research Scholarship he holds. Mr. J. Shaw read a paper, supplementing a former disquisition, on "Moulding Sands."

THE INFLUENCE OF SILICON ON THE CORROSION OF CAST IRON.*

BY J. NEWTON FRIEND AND C. W. MARSHALL.

OWING to its relatively low melting point, the ease with which objects may be cast from it, and their extreme hardness when completed, cast iron is now being used for commercial purposes in ever-increasing quantities. It is eminently desirable, therefore, in view of the serious nature of the corroding influences to which articles are exposed, to determine what the influence of varying constituents may be on the corrodibility of cast iron, and to learn what particular compositions offer the optimum resistance to corrosion. Hitherto but little work has been done in this connection, which affords a wide field for research, inasmuch as the chemical composition of cast iron and the physical conditions at the time of experiment admit of enormous variation. The problems are in consequence proportionately complicated, and a vast amount of work remains to be done before generalisations of any real value can be made. In the present paper the authors give the results of a study of the influence of silicon upon the corrodibility of cast iron.

For many years chemists have recognised that the presence of alloyed silicon tends to retard the corrosion of iron. Thus, Mallet more than 70 years ago was aware that cast iron rich in silicon is less readily attacked by acids, and Jouve has recently proved that alloys of silicon and iron containing 20 per cent. of the former element are remarkably resistant to acid attack. But alloys such as these are not cast iron, and their utility is greatly restricted by the difficulty of working them on account of the peculiar properties imparted to them by the silicon. The authors have therefore confined their attention to the influence on corrodibility exerted by a silicon content varying from 1·24 to 2·28 per cent. They would gladly have extended this series had it been possible, but the advantage of studying this particular range is twofold: (1) It covers many of the various silicon contents usually met with in commercial cast irons, and the results are not therefore of purely scientific interest. (2) The silicon is never so great as to interfere with the nature of the carbon content.

The latter is a most important point, and one to which we hope it may be possible to give further attention at a later date. As is well known, the presence of silicon tends to throw out the carbon as graphite, thereby rendering the metal porous and more liable to corrosion. Consequently, unless particular care be taken to keep the carbon in the same condition, both physically and chemically, the influence of the silicon *per se* upon the corrodibility of the metal must be affected by the proportion of graphitic carbon, and the results rendered misleading. The various cast irons used in this research were especially prepared for the authors by Messrs. Green & Co., of Wakefield, and they have pleasure in acknowledging their indebtedness to the manager, Mr. W. B. Greener, for his kindness. The irons were cut into blocks measuring 4·8 × 1·1 × 1·5 cubic centimetres, and after rubbing with emery paper were tested in this form. The authors wish also to thank Mr. A. E. Page, chemist to Messrs. Green & Co., for kindly analysing the metals for them. The results of these analyses are given in Table I.

TABLE I.

Percentage Composition.

Cast Iron No.	Silicon.	Graphite.	Combined Carbon.	Manganese.	Sulphur.	Phosphorus.
1	1·24	2·70	0·65	0·63	0·096	0·99
2	1·29	2·65	0·68	0·75	0·093	1·05
3	1·45	2·55	0·65	0·89	0·082	1·04
4	1·55	2·70	0·67	0·86	0·079	1·02
5	1·72	2·75	0·61	0·75	0·085	1·06
6	2·04	2·60	0·51	0·86	0·115	1·09
7	2·28	2·75	0·55	0·69	0·076	1·04

It will be observed that, with the exception of the silicon, the other elements are present in the cast iron in remarkably uniform proportions. The corrosion of the samples contain-

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ing the lowest quantity of silicon (No. 1) is in all the accompanying series taken as 100, the corrodibilities of the other samples being expressed accordingly.

Tap-water Tests.—The samples of iron were laid on sheets of paraffin wax in glass beakers containing 500 cubic centimetres of tap water, as described in another paper, contributed at this meeting by one of the present authors in conjunction with Messrs. West & Bentley (see page 519). After 17 weeks the irons were removed, carefully scraped free from rust, rinsed in alcohol, and dried in a steam oven. They were then weighed, the loss in weight being taken as a measure of the corrosion. The results are given in Table II.

TABLE II.—*Corrosion of Cast Iron in Tap Water (17 Weeks' Exposure).*

Cast Iron No.	Silicon per Cent.	Original Weight, Grammes.	Loss in Weight, Grammes.	Corrosion Factor.
1	1·24	57·0494	0·4040	100
2	1·29	57·3176	0·3276	81
3	1·45	57·6996	0·4098	101
4	1·55	54·5768	0·4028	100
5	1·72	56·9500	0·3980	99
6	2·04	59·4522	0·3846	95
7	2·28	57·6416	0·3554	88

Salt-water Tests.—These experiments (Table III.) were carried out in a precisely similar manner to the preceding ones, save that the liquid corrosive medium was 3 per cent. salt solution.

TABLE III.—*Corrosion of Cast Irons in 3 per cent. Sodium Chloride Solution (13 Weeks' Exposure).*

Cast Iron No.	Silicon per Cent.	Original Weight, Grammes.	Loss in Weight, Grammes.	Corrosion Factor.
1	1·24	57·0036	0·3134	100
2	1·29	57·3356	0·2882	92
3	1·45	57·6354	0·2974	95
4	1·55	54·9200	0·3112	99
5	1·72	57·2766	0·3182	101
6	2·04	58·5736	0·3172	101
7	2·28	58·5102	0·2758	88

Alternate Wet and Dry Tests.—These experiments were carried out in a precisely similar manner to those detailed in connection with nickel and chromium steels.* The results are given in Table IV.

TABLE IV.—*Corrosion of Cast Iron exposed to Alternate Wet and Dry (15 Weeks' Exposure).*

Cast Iron No.	Silicon per Cent.	Original Weight, Grammes.	Loss in Weight, Grammes.	Corrosion. Factor.
1	1·24	56·0926	1·0442	100
2	1·29	56·6978	1·2116	116
3	1·45	58·2680	1·0780	103
4	1·55	55·4664	1·0424	100
5	1·72	57·2854	1.0370	99
6	2·04	58·5464	1·0738	103
7	2·28	57·5996	1·0996	105

Sulphuric Acid Tests (0·05 per cent.)—These results (see Table V.) were obtained in an exactly similar manner to those with tap water, the corroding liquid in this case being 0·05 per cent. sulphuric acid, that is, 0·5 gramme of acid in 1,000 grammes of solution with water. The acid was renewed every 14 days.

TABLE V.—*Corrosion of Cast Iron in* 0·05 *per cent. Sulphuric Acid (13 Weeks' Exposure).*

Cast Iron No.	Silicon per Cent.	Original Weight, Grammes.	Loss in Weight, Grammes.	Corrosion Factor.
1	1·24	56·6814	0·5962	100
2	1·29	56·3498	0·6258	105
3	1·45	57·8794	0·5938	100
4	1·55	55·9416	0·5826	98
5	1·72	56·9324	0·6192	104
6	2·04	58·4756	0·6182	104
7	2·28	56·8700	0·6000	101

*Journal of Iron and Steel Institute, 1912. No. 1. p. 249.

Sulphuric Acid Tests (0·5 per cent.)—These experiments were similar to the preceding, save that stronger acid was employed, which was renewed every 14 days. The results are given in Table VI.

TABLE VI.—*Corrosion of Cast Iron in 0·5 per cent. Sulphuric Acid (13 Weeks' Exposure).*

Cast Iron No.	Silicon per Cent.	Original Weight, Grammes.	Loss in Weight, Grammes.	Corrosion Factor.
1	1·24	56·9196	5·4512	100
2	1·29	56·6360	5·4486	100
3	1·45	57·9528	5·3868	99
4	1·55	55·4094	5·4218	99
5	1·72	56·7000	5·5454	102
6	2·04	58·6396	5·7658	106
7	2·28	57·6414	5·7614	106

Discussion of the Results.—For the sake of facilitating the discussion of these results, Table VII. has been drawn up, in which the corrosion factors of the cast irons as obtained in the present research are grouped together.

TABLE VII.

Cast Iron No.	Silicon per Cent.	Corrosion Factor in					Corrosion Factor in 0·5 per Cent. Acid
		Tap Water.	Wet and Dry.	Salt Water.	0·05 per Cent. Acid.	Mean Factor	
1	1·24	100	100	100	100	100	100
2	1·29	81	116	92	105	98	100
3	1·45	101	103	95	100	100	99
4	1·55	100	100	99	98	100	99
5	1·72	99	99	101	104	101	102
6	2·04	95	103	101	104	101	106
7	2·28	88	105	88	101	96	106

A study of the above table reveals the following interesting facts: (1) The corrosion factors for the irons in acid and neutral media are almost identical. This is very remarkable in view of the divergence usually observed between the two in the case of steels. (2) All the irons corrode at a uniform rate, although No. 7 shows a slight tendency to corrode less rapidly in neutral solution. Possibly this indicates that if the percentage of silicon were raised still higher, without affecting the proportions of graphitic and combined carbon, a gradual increase in resistance to corrosion would be observed. We may safely conclude, however, that a variation in the percentage of silicon between the limits of 1·2 and 2·3 per cent. has no appreciable influence *per se* upon the corrodibility of the cast iron. If the relative proportions of graphitic and combined carbon are simultaneously varied with the silicon, a considerable difference in the corrodibility may be expected, and this is a point upon which the authors hope to throw further light at a future date.

The British Association.—The inaugural meeting of the 83rd annual meeting of the British Association for the Advancement of Science will be held in the Central Hall, Birmingham, on September 10th, when Sir Oliver Lodge will assume the presidency in succession to Prof. Schafer, and will deliver his presidential address. The evening discourses will be given, on September 12th by Sir Henry Cunynghame on "Explosions in Mines and Means of Preventing Them," and on September 16th by Mr. A. Smith Woodward on "Missing Links Among Extinct Animals." The concluding meeting is fixed for September 17th. The presidents of sections are: Mathematical and physical science, Mr. H. F. Baker; chemistry, Prof. W. P. Wynne; geology, Prof. E. J. Garwood; zoology, Mr. H. F. Gadow; geography, Prof. H. N. Dickson; economic science and statistics, the Rev. P. H. Wicksteed; anthropology, Sir Richard Temple; physiology, Mr. F. Gowland Hopkins; botany, Miss Ethel Sargant; educational science, Principal E. H. Griffiths; agriculture, Prof. T. B. Wood. Mr. J. A. F. Aspinall, who was appointed president of the engineering section, has been compelled to resign for reasons of health.

PRODUCTION OF SOUND STEEL BY LATERAL COMPRESSION OF THE INGOT WHILST ITS CENTRE IS LIQUID.*

BY BENJAMIN TALBOT.

In presenting this paper the author has accepted the invitation of the president of the institute, given at the last meeting, to make public the results of his work, and although the research is not completed, interesting and valuable data have, he believes, been obtained. This work is really a continuation and a development of the research carried out in the United States, which the author presented to the institute under the title "Segregation in Steel Ingots," in 1905. It was taken up again largely owing to the investigation work which has been, and is still, going on in the United States, with a view to ascertaining if a sounder and better rail could not be obtained at a reasonable cost.

The problem of producing a sound ingot is contemporaneous with the commencement of steel manufacture, and is a subject of vital importance. For the special steel trades the Whitworth and Harmet processes are employed, and in the steel-casting trade use is made of the sink head to fill up the cavity. What is desired now is some effective, economical method, which will approach the results obtained by the more expensive processes, so that the heavy cheap trades may be enabled to supply a perfectly sound material (especially rails) free from hidden defects.

Some authorities in America have expressed the opinion that the methods tried, and proposed up to the present, are not sufficiently practical or economical, and until this is accomplished, think it may be cheaper and safer to discard as much as 33 per cent. from the top of the ingot when used for rails, so that with the small crop from the bottom end, the yield of sound blooms would only be about 64 per cent. of the weight of the ingot. When one considers that this proposal, if carried out, means a most serious increase in the cost of producing steel, and that whilst perhaps at present it has only been suggested for rails, there would be no justifiable reason why it should not be extended to axles, sections, and plates used in other engineering requirements, the economic aspects of the problem will be seen to be of great importance. The idea of reducing some 25 per cent. more blooms to scrap value than is done to-day, which means the increase of ingot capacity by this amount if this loss is to be made up, or if this is not done, reducing the finished output to this extent, is a most serious addition to the cost in every department.

There is no doubt that the question of permitting ingots to cool to some indeterminate temperature, without considering what this really means to the ingot, has not received the consideration it deserves in steel manufacture, as this practice must mean a variation in segregation and cavities. It is clear that we cannot expect the same result from a large number of ingots, poured at or about the same time, from a number of furnaces, when these ingots are allowed to stand either in their moulds or stripped until their turn comes to be charged into the soaking pit, as this means a large variation in the time between pouring, stripping, and charging into the heating furnace of the various ingots. Whilst this practice may not be so objectionable in the soft steel trades for such products as ordinary sheet bars and billets for fencing wire, nails, &c., as no vital tests are required from these, yet a very different state of affairs exists when rails, axles, and other sections for engineering requirements are demanded.

The use of deoxidisers such as aluminium, silicon, and ferrotitanium diminishes segregation and removes blowholes from the outer areas, but they all create a characteristic deep conical central pipe, which may affect at least one-third of the ingot. We are therefore in the dilemma of having to sacrifice too large a percentage of the ingot if we use these deoxidisers to such an extent as to cause piping steel, for, as before stated, it will put a large additional cost on to the finished material. There is no doubt, however, if we were to cut off and discard the piped area in this class of steel, segregation would be practically eliminated in the blooms retained for use, say, 64 per cent., or less, of the ingot.

* Abstract of paper presented at the annual meeting of the Iron and Steel Institute, May 1st, 1913.

A normal ingot is bound to shrink when changing from the liquid to the solid condition. As the liquid steel runs against the cold iron surface of the mould a thin solid shell is immediately formed which fixes the size of the envelope. This solid shell gradually grows thicker and cannot contract to the same extent in the same time as the liquid centre does in solidifying. If it were practically possible immediately to follow up this shrinkage, and by continuous pressure to reduce the area of the mould gradually, and so reduce the area of the ingot whilst it is solidifying, no cavity would be formed.

In the method of the compression of ingots with liquid centres, which the author is now investigating, the casting and cooling of the ingots are regarded as skilled metallurgical operations. It is necessary to create and to observe a time-table between the time at which the ingot is poured, stripped, and charged into the soaking pit, and its area reduced by the preliminary operation. By reducing the cross-sectional area

Fig. 1.—Ingot A. No Aluminium. Ingot Cut through Centre.

Fig. 2.—Ingot B, 2oz. Aluminium per Ton. Ingot Cut through Centre.

at this time by means of lateral pressure, compensation is given for the contraction which is taking place within the mass, due to the solidifying and cooling that is going on in the centre of the ingot. When this has been accomplished, the reduced ingot is preferably returned to the pit or otherwise kept sufficiently hot for finishing.

After this preliminary work the element of time is no longer necessary as regards effecting the solidity and chemical formation in the mass, as the compression of the ingot fixes this, and even when kept heated for an indefinite period, no change is observed in the composition of the finished product, except such diffusion as may be expected from the elongation of the ingot in rolling into sections of various shapes. The ingot is preferably treated with a deoxidiser, such as aluminium, in order to create a piping steel, with no blowholes in the outer area. This gives a solid outer envelope, which is very important when compressing the ingot, as blowholes tend to weaken the shell, neither are they always eliminated when rolled down. The use of a deoxidiser also solidifies the metal earlier, so that the ingot can be stripped in less time than if none be used.

The action of aluminium in solidifying the metal is very clearly seen on examining the series of four ingots shown in Figs. 1-4. These ingots, 25in. by 25in. in cross-section,

weighed about 4¼ tons each, and contained about 0·65 per cent. carbon. They were charged into the pits in 32 minutes after teeming, so as to have liquid centres for a longer time than if they had been allowed to cool off in the atmosphere. They were heated up to the usual temperature, and then instead of being rolled were allowed to cool off. To ingot A no aluminium has been added, whereas to ingot B 2ozs. of aluminium per ton have been added. These two ingots have been cut open down the centre, and, as will be seen from the photographs, A has a large number of blowholes disseminated over the upper third, whilst in B blowholes are practically absent, but the typical aluminium cavity is plainly seen. Here we have two ingots with liquid centres charged at about the minimum time possible for this size of ingot, and although the pipe which has formed during the time that they were in the furnace is probably somewhat less than would have been the case if the ingots had been charged some half-hour later, yet there is still a well-defined shrinkage cavity formed during the solidification of the ingot. This cavity it would have had at the time of rolling down had the ingot been rolled instead of being allowed to cool out. In ingot B the cavity contained no gas, owing to a perforation having formed in the bridge over the roof of the cavity. The other two ingots on C and D, from separate heats, are really only shells from which the liquid interior has been purposely bled immediately after they were stripped, that is, some 25 minutes after pouring. It will be observed that in ingot D, to which aluminium was added, there is a perfectly solid envelope, or bottle, with walls 5½in. thick, which held a liquid centre, and in the normal course would grow thicker whilst being heated up in the pit. In the case of the companion ingot C, in which no deoxidiser was used, there is a wall only 4½in. thick, honeycombed with blowholes in the top portion, and with a very thin cap on the top.

This test goes to confirm the statement which the author made in his previous paper on "Segregation," that aluminium does solidify the metal quicker than when none is used, and therefore helps to diminish segregation. As might be expected, the surface of the inner wall is lower in carbon, &c., than the solid mass, as the purer metal attaches itself to the wall first. In the bottom portion of the shell, ingot D, some segregated metal from the top, which had been trapped when the liquid centre was being drained, was found.

In Figs. 5, 6, and 7 are shown the sulphur prints of three 25in. by 25in. ingots, which have been squeezed and compressed to 18in. by 18in., whilst their centres were liquid. In A no deoxidiser was used, and whilst the cavity does not exist, the blowholes which form in the envelope, which is solid when compression occurs, are not eliminated. In B silicon has been used, and in C aluminium, and the result is the same in both cases, there being no cavity and no blowholes, and therefore a solid mass.

These compressed ingots have been cut through their centres longitudinally, and the sulphur print reveals a very interesting phenomenon. It will be observed that in all three cases segregation is not found in the usual place, namely, in the central area of the upper portion, but that wherever pressure has been applied before solidification of the central portion has taken place, segregation has been formed upon and in the inner wall of the solid envelope, in the shape of a deposit higher in carbon and sulphur, of somewhat regular composition. It is this formation which has caused surprise amongst some of our well-known metallurgists. Dr. Stead has explained it by a very beautiful theory, which the author believes Dr. Howe accepts. Anyway, whatever theory may be the correct one, we have to accept it as a fact that if ingots are reduced in area whilst some portion of their centres are liquid this formation occurs, and the conical pipe or cavity does not exist as it otherwise would.

The most important point to settle in reference to this method of solving the problem is to determine what this treatment, with its characteristic formation, really means to the physical properties of the steel in the finished product, as compared to what we obtain with present-day practice from the upper portion of the ingot. We have also to consider the extent of this segregation and ascertain if it is sufficient in amount to be detrimental. Segregation in ordinary steel practically confines itself to the non-metallic elements—sulphur, carbon, and phosphorus. Fortunately, the percentages of increase in the metallic elements, such as manganese, and in silicon, do not fluctuate to any appreciable extent in a normal good heat of steel. With rails made largely by the basic open-hearth process, the segregation of phosphorus can be neglected, as this element will only average about 0·03 per cent., and an increase up to 0·04 per cent. in the restricted segregated area is of no moment.

If we look at the photographs of the sulphur prints of these compressed ingots with liquid centres we shall see the black line containing the segregated area. The author desires to point out that these prints are used as graphic illustrations, and were purposely made readily to locate the areas of increased sulphur percentage, but they are somewhat deceiving and unnecessarily alarming to the eye until compared with the analyses. Increases in the carbon and phosphorus will also be found in the enriched sulphur area, as these bodies migrate together in different percentages.

It will be observed that the diffused segregated area is very small when compared with the area of the outer solid envelope and the purer central portion. It is found that the thick outer envelope of ingots to which a deoxidiser has been added consists of steel of the normal analysis of the heat, and that the carbon in the darker ring averages some 15 to 20 per cent. higher, and the sulphur some 35 to 40 per cent. higher than in the normal metal. In any case, the place in which the excess is found is not so harmful as it is under the usual condition. In ordinary practice, where deoxidisers are not added, segregation is erratic, the segregate being found in and around the walls of the cavity, so that we have the double disadvantage of trying to weld up spaces surrounded by very unsuitable metal in the centre of the ingot.

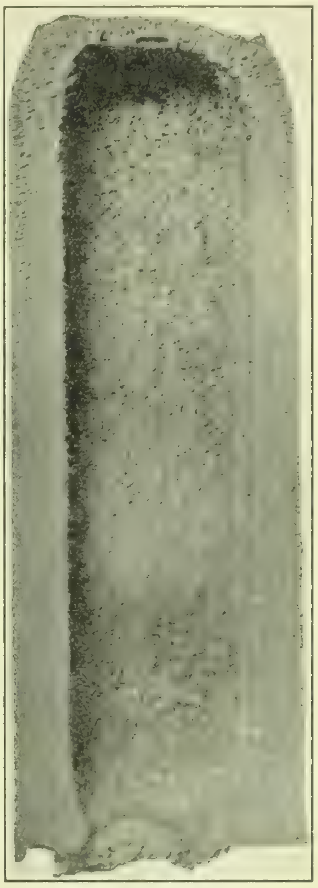


FIG. 3.—INGOT C, BLED INGOT TO WHICH NO DEOXIDISER WAS ADDED. INGOT CUT THROUGH CENTRE.

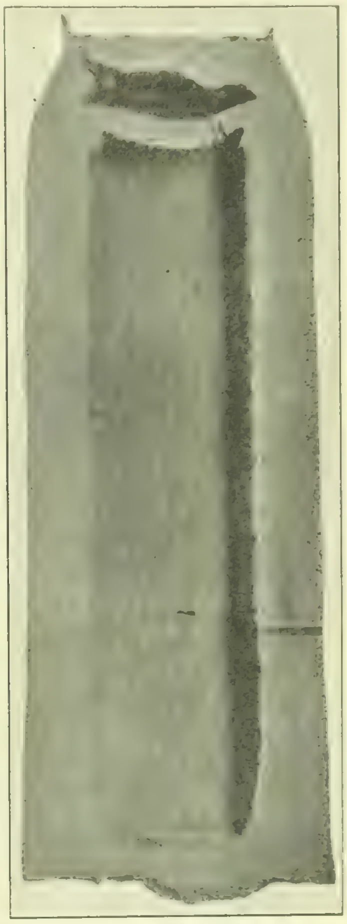


FIG. 4.—INGOT D, BLED INGOT TO WHICH 2oz ALUMINIUM WAS ADDED PER TON INGOT CUT THROUGH CENTRE

In the cooling and solidifying of ingots we have to contend with the forces of nature. We have liquid iron, containing a few other elements, at a very high temperature, consequently, in a great state of expansion, and in the best condition therefore for absorbing gases. For some trades operators dead melt their steel, but they invariably use some powerful deoxidiser, such as silicon, and produce a solid piping steel. In the ordinary trades, such as we are now primarily considering, the

author has heard authorities object to the use of aluminium for reasons apart from the formation of the well-known central pipe, such as the fact that the oxidation product produced by aluminium may be left in the steel. As the author has been adding aluminium to the top portion of ingots for 20 years, he can say that he has never come across the oxidation product from 2ozs. of aluminium per ton enclosed in the steel, and he doubts if it could be found, even if there, when added in such small quantity. He does not agree with this objection, because, so far as producing a good surface on sections with flanges is concerned, there is no comparison between the steel from the top portion of the ingot to which aluminium has been added and steel to which no special deoxidiser has been added. It is unfortunate that the pipe formation is so large, as the mechanical tests are better and the segregation is decreased.

If Figs. 1-4 be inspected, the reason for this is plainly seen,

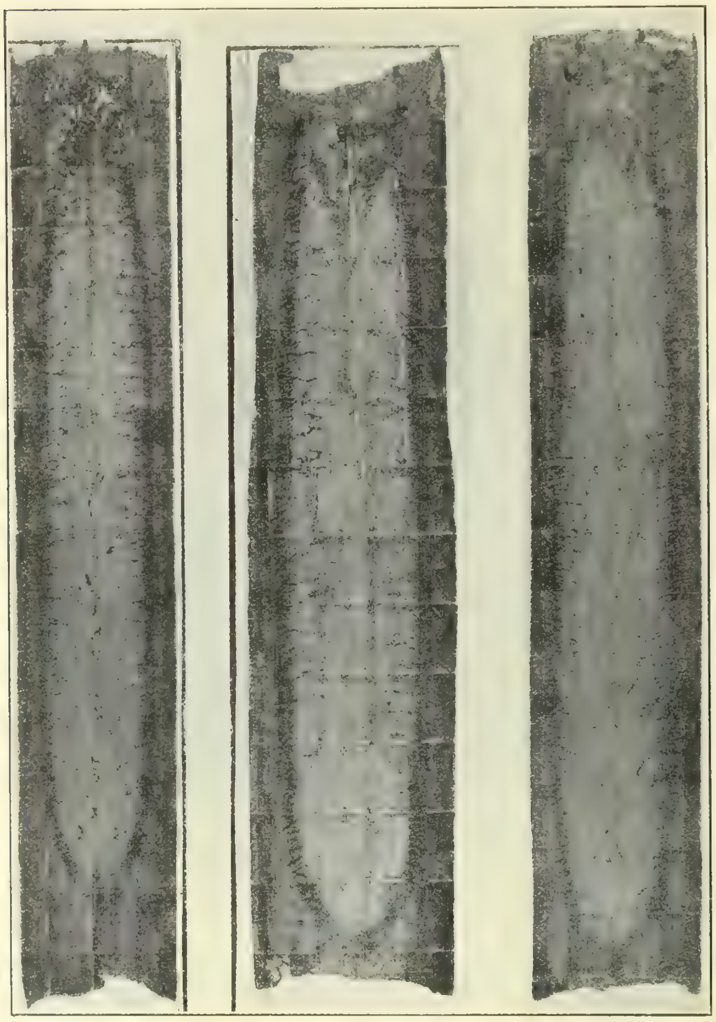


FIG. 5. FIG. 6. FIG. 7.

Fig. 5. Ingot A. No deoxidiser used. Compressed with liquid centre. 25″×25″. Ingot compressed to 18″×18″. Cut through its centre longitudinally.

Fig. 6. Ingot B. Silicon added. Compressed with liquid centre. 25″×25″ ingot compressed to 18″×18″. Cut through its centre longitudinally.

Fig. 7. Ingot C. Aluminium added. Compressed with liquid centre. 25″×25″ ingot compressed to 18″×18″. Cut through its centre longitudinally.

as the envelope of the ingot to which aluminium has been added is perfectly solid, and consequently will give a perfectly sound exterior to the finished article. With the companion ingot, however, without a deoxidiser a sound exterior will not be obtained with some sections from the top portion of the ingot where the blowholes exist. The pipe forms owing to the shrinkage of the metal whilst solidifying and cooling, and gases collect in the cavity. As far as the author knows, the pipe or cavity formed from this cause is confined largely to the top portion of the ingot, although the pipe may at times taper away into the lower half.

It may be of interest to note here the variation which occurs in the composition of the gas which fills these cavities when the ingot is dumped after stripping without reheating, when it is treated with or without aluminium, and when it is reheated. The following three analyses of gas from three ingots were made, the first two being from ingots to which no aluminium had been added, and the last from an ingot to which 2ozs. of aluminium per ton had been added:—

	1.	2.	3.
	Per cent.	Per cent.	Per cent.
Carbonic oxide	5·00	0·0	0·0
Nitrogen	3·67	4·40	19·34
Hydrogen	91·33	95·60	80·66
Total	100.00	100.00	100.00

In the first of these analyses the ingot was not reheated in the pit and had no aluminium added, whilst in No. 2 (from an ingot with no aluminium) and No. 3 (with aluminium) the ingots were reheated in the pit; and the author suggests, without formulating any theory, that this fact may account for the absence of any carbonic oxide in the gas from these two ingots, while there is 5 per cent. of carbonic oxide in the first, which was unheated. It is also worth noting in regard to these analyses of gases that in the case of the ingots to which no aluminium had been added, the percentage of nitrogen is comparatively low, whilst in the gas which formed in the cavity in the ingot to which aluminium had been added it reaches nearly 20 per cent., or about five times higher than in the other two. May not the aluminium addition have had some action in setting free this nitrogen from its combination with iron?

To improve the quality of the finished article, such as a rail, it would appear that in solid piping steel we have the condition which will yield the result if we can only remove the pipe or prevent it from forming. It is therefore to this problem that metallurgists and others skilled in the art should direct their attention. If we do not have solid piping steel, we have no solid outer envelope, but steel with blowholes in some portion of this area, and blowholes and cavities in the centre of the upper portion of the ingot, with segregate collected around these central cavities to an increased amount. The rail produced from such steel will not be so good as the rail produced from the solid steel, since the outside wearing surface will be softer and will contain some rolled-out blowholes, and will moreover have a hard and impure core due to the segregate, which may not be thoroughly welded together, consequently the best results in actual wear cannot be expected.

Whilst failures in the heads of rails are more numerous in the United States than from other causes, yet trouble is also experienced in that country with base failures. These, according to Mr. Cushing, are due to longitudinal seams in the base, and it appears probable that some of these seams result from the blowholes in the outer strata. This difficulty from blowholes will be overcome if we use steel, with a solid outer envelope, as shown in ingot B, Fig. 2.

In order to settle the question of the effect upon the finished rail of the lateral compression of the ingot whilst its centre is still liquid, very careful and extended tests have been made on many rails. As the drop test is the most reliable and effective practical test, this has been chiefly used. A drop test on 67 rails rolled from 10 $4\frac{1}{4}$-ton ingots compressed with liquid centres taken from 10 different rail heats of various analyses, sections, and specifications, was obtained from the top to the bottom of each ingot, in order to see if any practical differences could be observed in the deflections obtained, and also to ascertain if the rails would stand the standard drop test without breaking when taken from all positions in the ingot. No breakages occurred, and the deflections were found to be very satisfactory. If there had been any inherent physical weakness due to the compression of the ingot, whilst the centre was liquid, there would have been a number of breakages, as it is a severe test to subject every rail made to the drop test.

From the results obtained from the rails rolled from these 10 ingots, it was found that the yield of good merchantable rails of first quality was slightly over 88 per cent. on the ingot, and as these contain no pipe or segregation in the centre, but only a segregation to a known harmless amount in a well-defined position, such rails are more satisfactory, both as

regards yield and quality, than those made by ordinary every-day practice. Again, so far as the author's experience goes, no such product as a defective or second quality rail will be produced due to any surface defects, such as torn flanges and seams, as these do not exist in rails made from steel treated in this manner, so that there is thus a distinct saving in manufacture. The average weight of bloom scrap from the cogging mill over the 10 ingots was 4·68 per cent. on the ingot, and this is satisfactory. The rail crop averaged 4·06 per cent. on the bloom, and as this rail crop scrap in the particular rail mill used will be practically the same from all kinds of sound blooms, the 88 per cent. of good merchantable rails and the 4·68 per cent. of bloom crops are the two important points to consider.

Photographs obtained of the etched sections from the bottom of a number of rails rolled from two pressed ingots with liquid centres showed the solid outer envelope surrounding the sides and the top and bottom of the rail. This formation is always found in rails when made from ingots which have been compressed before their centres have solidified, and the analyses vary over the cross-section of the rail in a regular manner.

The author has already drawn attention elsewhere to the advantage that would accrue if the mechanical tests on rails could be made on the whole of the head, instead of, as at present, from a test-piece machined from a definite part of the head. Unfortunately, our present machines are not sufficiently powerful to admit of this being done. As the next best alternative, the author has had some rail heads rolled down to 1in. square, and has tested the resulting bars in the ordinary testing machine, with the results given below. In order to determine whether the results obtained are comparable with those obtained from the ordinary test-pieces, a test-piece was also cut from the head from another rail from the same cast, the results from which are also given.

	Breaking Strain per sq. inch.	Elongation on 2 inches.
	Tons.	Per cent.
Ordinary test-piece from untreated rail head	58·1	12·0
Ordinary test-piece from laterally compressed ingot	56·1	11·5
Rail head from untreated ingot rolled down to 1in. square	54·5	14·0
Rail head from laterally compressed ingot rolled down to 1in. square	54·5	15·0

In the above case the carbon in the heat was 0·63 per cent. Another rail somewhat lower in carbon from a laterally compressed ingot gave, when the head was rolled down to 1in. square, 49 tons tensile per square inch, and 22 per cent. elongation on 2in., whilst a rail from an untreated ingot from the same cast gave 49·3 tons tensile, with 19 per cent. elongation on 2in., thus showing a very close agreement between the two.

The preparatory compression process has also been applied to ingots from soft steel heats for structural purposes, such as bulb angles, channels, joists, rounds, &c. The same characteristic structure is observed in the larger sections in these shapes, namely, the outer envelope, a darker line, and a purer central portion, when the sections are etched. The mechanical tests on these sections are found to be quite normal.

On some of the experimental ingots compressed with liquid centres, the temperature was taken by means of the Féry radiation pyrometer, both at the time at which the ingot was stripped, and also immediately it entered the cogging moulds, and the skin of oxide dropped off. The two following examples will show the temperatures obtained :—

Temperature at stripping and before charging into the soaking pit	1,070° C.	1,045° C.
Temperature at cogging rolls	1,155° C.	1,180° C.

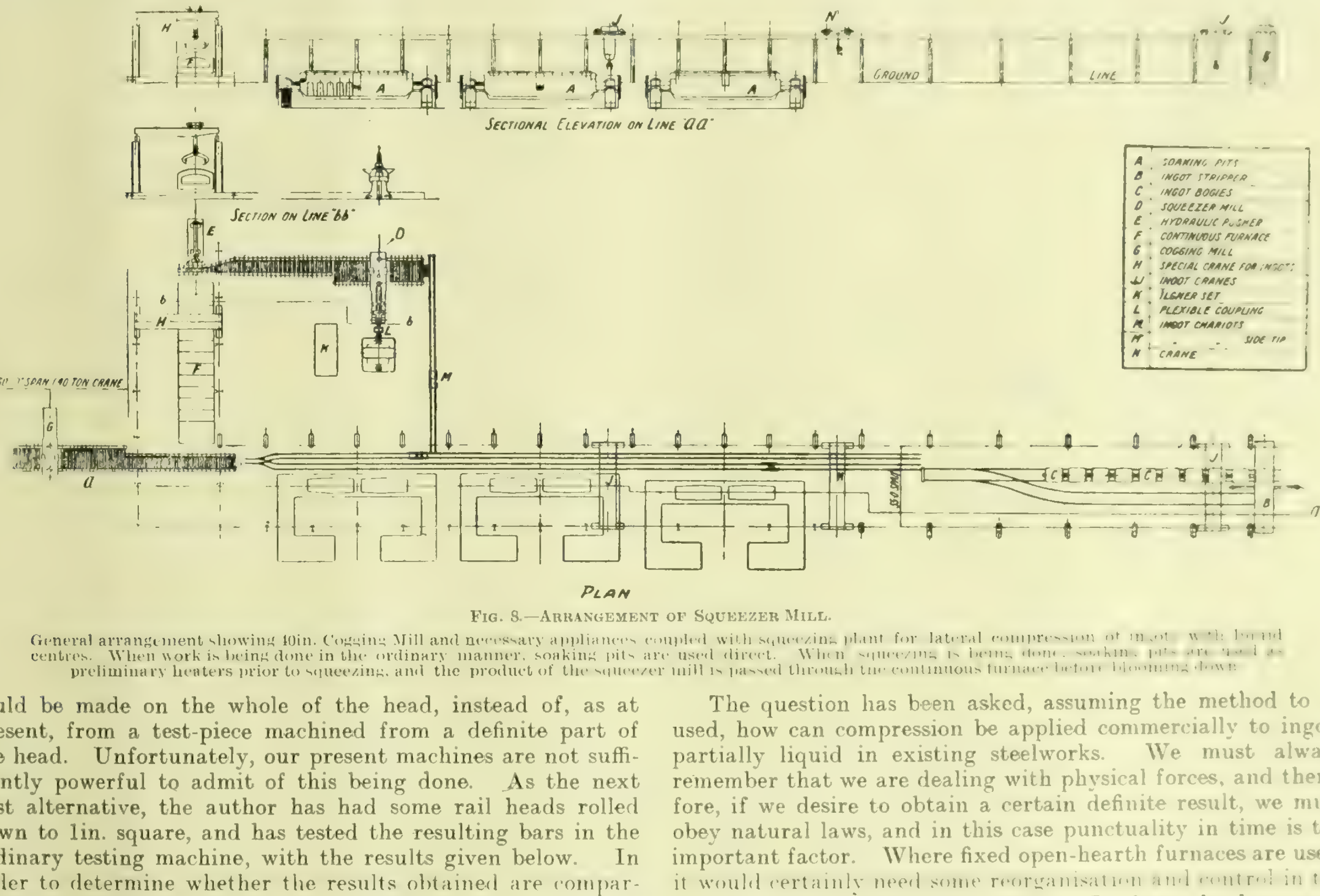


FIG. 8.—ARRANGEMENT OF SQUEEZER MILL.

General arrangement showing 40in. Cogging Mill and necessary appliances coupled with squeezing plant for lateral compression of ingots with liquid centres. When work is being done in the ordinary manner, soaking pits are used direct. When squeezing is being done, soaking pits are used as preliminary heaters prior to squeezing, and the product of the squeezer mill is passed through the continuous furnace before blooming down.

The question has been asked, assuming the method to be used, how can compression be applied commercially to ingots partially liquid in existing steelworks. We must always remember that we are dealing with physical forces, and therefore, if we desire to obtain a certain definite result, we must obey natural laws, and in this case punctuality in time is the important factor. Where fixed open-hearth furnaces are used, it would certainly need some reorganisation and control in the casting and stripping department. In fact, the happy-go-lucky days in this department will be over, and a strict time-table would have to be observed under skilled supervision, in order to supply the preparatory compressing plant in a satisfactory manner. The practice of a considerable number of furnaces tapping as they like, at the same time, as is common to-day in shops containing a large number of fixed furnaces, would be stopped. A better sequence in the tapping of the furnaces would be required, and in this, and in other respects, the 200-ton tilting furnace is a more suitable apparatus to use than its smaller fixed competitor. There would not be this trouble where Bessemer steel is used, as the heats follow each other in steady progression.

To get good results ingots of, say, 20in. by 24in. or 25in. by 25in., ranging from $3\frac{1}{2}$ to $4\frac{1}{4}$ tons, are suitable, although, if the method comes into use, larger ingots will be employed in some cases. In fact, in this method of treating ingots, the increase in weight will be an advantage, as a greater range in

the critical time period occurs, that is, the minimum and maximum time between which one can obtain the formation, and produce a sound mass. As heavy machinery would be installed, there would be a distinct saving in handling larger ingots. The small ingot, with the old-fashioned expensive sunk pit, will not be used, and casting on cars could be adopted with advantage with the use of the overhead stripper system.

If we consider a moderate output, such as could be obtained from a mill in this country, we can assume that a cogging mill will cog down 25in. by 25in. ingots to 8in. by 8in. blooms, and that it works 107 actual working hours during the week, and further that it deals with 1,200 tons of ingots per 24 hours, or 60 tons per working hour, which would give 6,420 tons of ingots in the working week. The casting and preparatory compression processes would have to keep ahead of this. If it were possible to tap the furnaces regularly it would only mean one 60-ton heat per hour, but the preparatory plant could be arranged to take two heats, which may be tapped and poured at the same moment, therefore its capacity must be equal to 120 tons in any one hour, even if it did no work for the next hour. In 120 tons there would be 28 ingots of 25in. by 25in. size. It takes about 20 minutes to pour a 60-ton heat when using $1\frac{1}{4}$in. nozzle, and larger nozzles should not be used. To be safe, a 25in. by 25in. ingot, when aluminium is used, should not be stripped under 25 minutes from the time it is poured, as otherwise it may bleed if lifted off the bottom plate.

The heat is run under the travelling stripper under the time of 25 to 30 minutes, and the stripper will strip the ingots in the order in which they were cast in a steady progression. The stripper will easily strip the ingots in less time than it took to cast. Occasionally, two heats may have to be dealt with at the same time, and in this case, the spare stripper will help at the work, so that uniform time may be kept. Ample soaking-pit capacity will be provided to find room for the ingots as soon as they are stripped.

If a reversing set of rolls be used in the preparatory plant to compress the 25in. by 25in. ingot down to about 19in. by 19in., there will be sufficient time to do this work, seeing that the cogging mill has to roll down the 19in. by 19in. to 8in. by 8in. For larger outputs, a continuous set of rolls could be installed for the preparatory process.

Although the exact minimum time in which an ingot can be drawn out of the soaking pit, after its envelope has been heated up and thickened, will vary with the size, yet it must be left there for a sufficient length of time to permit the shell, especially on the top and bottom, to thicken and to become sufficiently strong to resist the pressure of the rolls without rupture. The range in time between the minimum at which the ingot can be drawn, and the maximum before the centre becomes solid, also varies with the size of the ingot.

The time used on 10 ingots of 25in. by 25in. size averaged 29 minutes between the time of pouring and stripping the mould from the ingot, and 58 minutes from the time of stripping the ingot and drawing it from the pit for the preparatory compression. Fig. 8 shows the ground plan and elevation of a suggested lay-out for carrying out the process.

From the foregoing it will be seen that in dealing with ingots of $3\frac{1}{2}$ to 4 tons weight (which is a size which is probably more used than any other for rails) lateral compression of the ingot is effected at the time when the last portion of the centre is liquid. If solidification of the ingot is to be brought about by any method of feeding from a sink head, then the sink head must be kept liquid until shrinkage is complete. We see from the photos of the bled ingot (Figs. 3 and 4) that at 25 minutes after teeming the entire centre of this 4-ton ingot was still liquid, and the shrinkage had still to occur in this portion of the ingot, so that to fill up the shrinkage cavity by any method of feeding, the ingot must remain in the mould until it is solid throughout, the top being kept liquid during the whole time.

This investigation shows that it is quite feasible to obtain a perfectly sound product in finished sections, and that even when deoxidisers are used, piping can be obviated in such product with only a very small discard in the way of bloom crops, [illegible] economical preparatory treatment described, which treatment results in a considerably lessened percentage of scrap as such or as defective material over to-day's practice, and an appreciable increase in the yield of merchantable product, with consequent economy in production. It also appears that the typical formation developed by laterally compressing an ingot whilst its centre is liquid gives more regular and better physical results on all kinds of mechanical tests taken from the upper portion of the ingot over those obtained in to-day's practice from the same position in the ingot.

The foregoing results and conclusions are based upon the investigation of more than 100 large ingots, and the author has no hesitation in saying that anyone following the method he has outlined with ordinary care will be able to obtain similar results on ingots of approximately the same size. The investigation has extended over several years, and has necessitated a vast amount of detailed work.

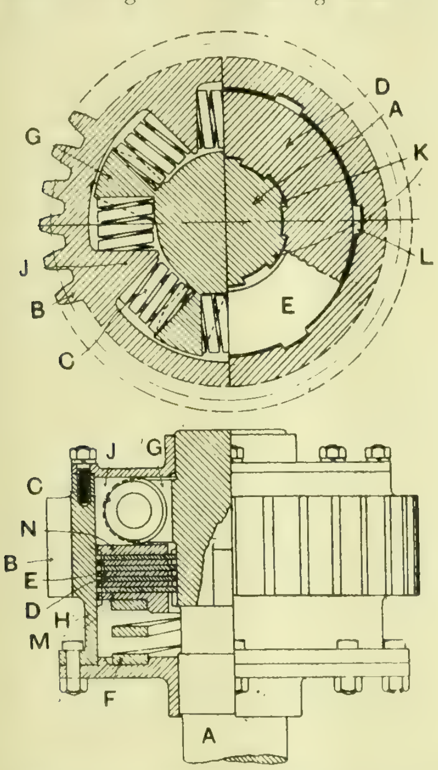
RESEARCH STUDENTSHIPS IN HEATING AND VENTILATING ENGINEERING.

Two Heating Studentships, tenable in the Faculty of Engineering of University College, London, each of the value of £50 a year, together with 11 guineas, being the amount of college fees—Regulation 2—may be awarded by the Institution of Heating and Ventilating Engineers. Candidates must produce evidence that they have already pursued a course of engineering training and are familiar with the work of an engineering laboratory. Their applications should be accompanied by not more than three recommendations from the professors or other responsible persons under whom they have worked. Evidence in the form of laboratory note-books, drawings, and the results of any research already carried out will be accepted in support of applications. Importance will be attached to a good knowledge of French and German. Candidates who cannot produce adequate evidence of the results of previous training may be examined in the following subjects: Mathematics, pure and applied; one or more branches of engineering science; French and German; physics; chemistry. The standard in each subject will be that required for the Bachelor of Science in Engineering in the University of London. There is no limitation of age for candidates, and no restriction as to the previous place or places of education. The qualifications of candidates will be reported on, and the examination—if any—will be conducted by a Board of Examiners appointed by the University College Faculty of Engineering, assisted by two assessors appointed by the Council of the Institution of Heating and Ventilating Engineers. The award will be made on the report of the Board of Examiners by the Council of the Institution of Heating and Ventilating Engineers. The conditions of tenure are as follows: (1) The research students will be required to devote their whole time to their work and to pursue such courses of study in connection therewith and to undertake such researches as the Faculty of Engineering of University College may approve. The research students may be required to continue their work during the vacations or parts of them. (2) The research students will be required to pay to the College a registration fee of one guinea a year, and a composition fee of ten guineas a year, the payment of which will entitle the students to full privileges at University College, including membership of the Union Society. (3) The studentships will be awarded in the first instance for one year and are renewable for a second year, subject to the work of the research students being satisfactory; they may, under exceptional circumstances, be renewed for a third year. (4) The research students must present to the Faculty of Engineering and to the Institution of Heating and Ventilating Engineers the results of their investigations in a form suitable for publication, and no account of the work may be published without the consent of these bodies. The research students will begin their work on September 30th, 1913, unless other arrangements are sanctioned. Candidates holding appointments or engaged in business will be given adequate time to meet their existing engagements, always provided that their work at the College must be begun not later than January 1st, 1914. Applications should be sent to Mr. Walter W. Seton, M.A., secretary, University College, London (Gower Street, W.C.), on or before Saturday, June 14th, 1913.

GEARING FOR THE TRANSMISSION OF ROTARY MOTION.

WITH the object of eliminating certain forms of irregular angular velocity or torque in the driven element of gearing for the transmission of rotary motion, Messrs. Rolls-Royce, Ltd., of Derby, have designed and patented the arrangement illustrated in the accompanying sectional views, in which a spring or elastic buffer drive and a spring-controlled frictional damper are interposed between the driving and driven elements of the gearing, the construction and arrangement of the devices having the following characteristics: (1) That the spring or elastic buffer drive can alone transmit the whole of the drive; (2) that the spring-controlled frictional damper cannot efficiently transmit the drive; and (3) that the two devices function independently, that is to say, each performs the function it is designed to perform independently of the other.

In the transmission of rotary motion from prime movers, rotary vibrations are frequently set up in the transmission shafts when such shafts have a natural elasticity in a rotary direction. These vibrations arise from the variations in angular velocity or torque which occur during each revolution and are found more particularly when the driven part includes a member of appreciable flywheel effect. For the purpose of eliminating or diminishing these variations in



GEARING FOR TRANSMISSION OF ROTARY MOTION.

angular velocity or torque, a spring or elastic buffer drive has sometimes been employed, but in many cases the effect of this is that the relative rotary movement which consequently occurs between the driving and driven members of the transmission system develops into objectionable periodic or synchronous rotary vibrations. By the construction illustrated the transference of irregularities in angular velocity or torque between the members is, it is claimed, completely or partially prevented, and any slight remaining irregularities of angular velocity or torque are prevented from developing into periodic or synchronous rotary vibrations.

Referring to the illustrations, the shaft A has four outwardly projecting radial lugs G equally spaced. The gear wheel B from or to which is transmitted the rotary movement of the shaft A has its boss H made of annular box-like form and has its ends closed by plates. This boss carries within it four lugs J which project inwardly and alternate with the lugs G. Interposed between these lugs are spring buffers C which are stiff enough to transmit the whole of the drive. Mounted on the shaft A by means of castellations K formed on its external circumference are a series of friction discs D, and mounted in a similar manner on castellations L formed on the internal circumference of the boss H of the wheel B are a series of friction discs E which alternate with the discs D. These friction discs are kept in contact with one another by means of a spring F which operates between a specially shaped end friction disc M and end cover plate. The strength of the spring F is such that it cannot transmit the drive so that the device can only function as a vibration damper. The other end friction disc N is suitably strengthened and contacts one side of the lugs J and the other cover plate contacts the other side of the lugs J. The lugs G are made slightly narrower than the lugs J so that they are free to move in a rotary direction independent of the gear wheel B and its box-like boss.

The mechanism is operative in either direction, that is to say, the rotary motion can be transmitted from the shaft A to the gear wheel B or vice versâ, the drive being taken through the lugs G and J and through the spring or elastic buffers C, the spring or elastic buffers allowing the driven member to move relatively to the driving member in a rotary direction about its axis within certain limits, but these relative rotary movements of the driven member are prevented from developing into objectionable rotary vibrations by means of the damping action of the friction discs D and E.

TIDAL WATERS AS A SOURCE OF POWER.

AT a meeting of the Society of Engineers (Incorporated), held on Monday, May 5th, a paper on "Tidal Waters as a Source of Power" was read by Mr. C. A. Battiscombe, the object of the paper being to draw attention generally to the commercial possibilities of hydro-electric installations in the British Isles, more particularly with regard to the use of the tides. After some introductory remarks in reference to tidal intervals and the range of neap tides, the author pointed out that in this connection the head of water available for actuating turbines could not exceed one-third of the range of minimum tides. The form of installation required for a continuous output of power was then discussed, the chief objections to twin installations, so placed that the tidal interval at the one would not synchronise with the tidal interval at the other, being pointed out. An outline was given of the arrangements proposed for the constant maintenance of a working head, by means of a chamber for the turbines, connected by valves to the tidal way and to three reservoirs in which the tidal water might be impounded, and to this was added a description of the proposal of sequence of flow between the tidal way and the reservoirs.

The author claimed that the utilisation of the tides for power purposes presented few engineering difficulties as far as principles were concerned, but that the real difficulty lay in the question of cost, and therefore in the choice of the site and in the design of the structural details. The expenditure on commercial works that an engineer was justified in recommending was suggested, and some explanatory remarks were offered in respect to various items given in the rough estimate and to the principles governing the economical capacity of a proposed installation for any range of tide. The rough estimate followed next and the cost of the Board of Trade unit, obtained from the proposed installation, was then considered from the point of view of supply and demand, both from a commercial and a municipal standpoint, on the basis of annual expenditure over a period of 30 years. The paper concluded by insisting on the importance of regarding the supply of fuel as a matter that concerned the whole nation; that the demand for combustible fuel was continually increasing, and that coal being practically the only fuel found in England, it would be mere folly to neglect any other available source of energy whereby the present rate of consumption of coal might be sensibly reduced. It was submitted that not only could the tides be utilised as a constant source of power, but that, taken in conjunction with the power that could be derived from fresh-water rivers, their utilisation would be a great gain to the commercial and industrial interests of the United Kingdom.

Mining Electrical Engineers.—A meeting of the West of Scotland Branch of the Association of Mining Electrical Engineers was held on the 18th inst. at Glasgow. It was announced that the Council had unanimously recommended the re-election of Mr. Matthew Brown as president, Mr. A. B. Muirhead as vice-president, and Mr. D. Martin as secretary for the ensuing year.

THE SMOKE PROBLEM FROM AN ECONOMIC STANDPOINT.*

BY CHARLES W. FULTON.

IN presenting to you the following remarks on the smoke problem, I want to make it clear that I come before you not as an expert on this subject, but only as one who has had to consider the smoke problem as a user and from a purely commercial standpoint. Many things can be done, but are not, simply because in practice it costs money to do them. All our rivers could be made perfectly pure, but, if the law were rigidly enforced in all cases, many concerns would have to close up. In short, if in practice it paid to consume smoke, none would be made.

Now, to arrive at a sound conclusion as to whether the installation of a smoke-consuming system will pay or not, it is necessary to take a more comprehensive view than that usually taken by those in control of a works, because in many establishments the steam-raising gradually settles down to a more or less fixed procedure, and, as a consequence, when a new system is placed before the manager with what often appears to be excellent guarantees of economy, the manager (a little apathetic as regards this department) forgets certain factors which must, of necessity, be taken into account before he can be assured that the installation will lead to a better balance-sheet, which is the only vital question for him to consider. It is simple enough to run an installation of boilers without smoke by supplying a sufficient excess of air to kill same, but this costs money.

The two important factors which must be considered are: (1) Coal efficiency, *i.e.*, pounds of water evaporated per pound of coal burned. (2) Boiler efficiency, *i.e.*, the total evaporation per boiler.

By putting down plenty of boilers and steaming them slowly, it is a comparatively easy matter to get no smoke and a high coal efficiency, but this does not pay, because of the increase of the following factors: Capital, interest, upkeep, depreciation and labour cost on boilers, housing, space, and attachments. Therefore it becomes apparent that a guarantee of reduction on the coal bill by itself is no assurance of a commercial advantage or a better dividend. In individual concerns these factors are not sufficiently realised, but in the case of the larger combines with central offices, where it becomes possible to compare one mill against another, and that from a dividend point of view, it is now recognised that, while the highest coal efficiency can be got at, say, round about 20lbs. to 25lbs. of coal burned per square foot of grate area, the most economical rate of burning from a profit point of view is much higher, say about 30lbs. to 40lbs. per square foot, depending upon circumstances.

In looking at the question of the smoke problem, it naturally divided itself into two main headings: (1) How are presently-installed steam-raising installations to be made smokeless with an increase of profit? (2) What is the best system of smokeless steam-raising to adopt for new establishments?

The questions to consider under these two headings are quite different, because in the first case the capital is already sunk in plant, whereas in the second case the capital is there to be spent in whatever direction seems best from a commercial standpoint. Referring to the first heading, there are several mechanical stokers on the market which can be made to work smokeless and give a good coal efficiency; the advantages and disadvantages of these are known, so that I need not here enter into a discussion of them. Speaking generally, however, the experience of these systems seems to be that they have the common commercial disadvantage of a too limited output of steam per boiler, or, in other words, they only give high coal economy and smokelessness within too limited a range of output, and, from a business point of view, a high boiler efficiency is as important as a high coal efficiency.

When fresh coal is thrown on to a fire it becomes an absorbent of heat, which goes to volatilise the bituminous portion of the coal; this is a cooling process which means that the carbonaceous part has to wait its turn to receive heat sufficient for its own combustion. It is apparent therefore that to have a smokeless chimney the products of distillation should be produced continuously, and these products be constantly consumed by bringing them into as high a temperature zone as possible, because when this is done intermittently it means a sudden cooling effect simultaneously with a large increase of volume, both factors leading to smoke.

As the smoke problem resolves itself into an economic problem, a study of the economic requirements becomes necessary. The main sources of loss in steam-raising are:—

(*a*) The lost heat carried away in the gases passing up the chimney.

(*b*) The loss due to incomplete combustion of the carbon in the coal.

(*c*) Loss due to imperfect firing, such as holes forming in the fire which allow a large excess of air to pass unutilised, and which amounts to cooling the fire with a stream of air which gets heated up only to carry the heat units away into the atmosphere.

(*d*) Loss due to open doors while cleaning the fires, allowing an excess of unutilised air to pass into the furnace

These sources of loss, speaking generally, become greater as the duty of the boilers is forced up beyond, say, 20lbs. to 25lbs. of coal burned per hour per square foot of grate area, but the boiler efficiency (*i.e.*, output) must of necessity be considered along with the coal efficiency in the study of this problem from an economic standpoint.

Referring to (*a*): 1lb. of carbon contains, say, 14,500 B.Th.U. of heat. Suppose we burn completely 1lb. of pure carbon in the theoretically correct quantity of air, and supposing the residual gases to be at a temperature of 300° Fah. (above atmospheric temperature), we find that we have 920 B.Th.U. of heat passing up the chimney. If we are using twice the theoretical quantity of air, we lose another 855 B.Th.U., but in practice 600° Fah. is not uncommon, in which case our losses would be doubled, and in practice it is common to find more than double the theoretical quantity of air being used. From this it will be seen that any excess of air above the theoretical quantity means more lost heat, and, further, as much heat as possible should be absorbed into the water in the boiler so as to reduce the temperature of the gases passing up the chimney, as the loss under this heating is affected by both volume and temperature.

Now we have seen that it is essential for commercial reasons to get a high boiler efficiency; to do this we must burn in ordinary practice about 30lbs. to 40lbs. of coal per square foot of grate area, which necessitates a large excess of air to get the rate of combustion high enough. This excess of air, as above stated, means a loss of efficiency not only because of the extra volume carried up the chimney, but due further to the fact that the larger the volume the faster it must travel, and so the less time is given to it in contact with the heating surface of the boiler, and so the exit temperature is higher, hence we have (1) higher temperature, and (2) greater volume.

The natural suggestion that arises therefore as a means of meeting item (*a*) is to increase the quantity of coal under combustion, thus reducing the rate of combustion, or, in other words, give each pound of coal longer to burn. To make this point quite clear, suppose we have two fires of the same grate area, one with twice the quantity of coal burning as compared with the other, then, in order to get the same quantity of coal burned per square foot of grate area in both, the time given to burn 1lb. of coal in the one fire is twice the time given in the other; the rate of combustion being lower per pound, we can get the required quantity burned per square foot to give the necessary boiler efficiency with much less excess of air.

Referring to (*b*) (*i.e.*, loss due to incomplete combustion): If 1lb. of carbon is burnt to CO, 4,450 B.Th.U. are evolved, whereas when completely burnt to CO_2, 14,540 B.Th.U. are evolved. This shows the tremendous importance of getting complete combustion. A very high furnace temperature, and one that remains so uninterruptedly, will be the best conditions under this heating.

Referring to (*c*) (*i.e.*, loss due to holes forming in the fire): In practice, when steaming hard, it has been found almost impossible to keep holes from forming in the fire unless by highly-skilled hand-firing, and even under these conditions, if

* Abstract of paper presented before the Textile Institute at Manchester, May 2nd, 1913.

the fireman covers a bare place when firing, this place when he next fires is liable to be the heaviest portion. To solve this problem satisfactorily, it requires a condition such that, as soon as a hole tends to form through more rapid combustion at any place, more supply should automatically pass to that place.

In an experiment made expressly for the British Association assembled at Manchester as long ago as 1842, by Mr. Houldsworth, a charge of 3 cwts. of coal was thrown on a furnace, and the temperature in the flue rose in 25 mins. from 750 to 1,220°, when it began to fall to 1,040°, the fuel not having been disturbed during 75 mins. Perceiving the temperature in the flue to have become so low, Mr. Houldsworth had the fire levelled (*i.e.*, the vacant spaces covered), when the temperature suddenly rose from 1,040° to 1,150°.

Referring to (*d*): To meet this source of loss, all intermittent cleaning should, if possible, be eliminated, therefore removing the necessity for opening doors during the operation.

I shall here describe a somewhat novel system which seems to me to be a move in the right direction. In ordinary practice the firebars of a Lancashire or Cornish boiler are fitted across the diameter of the circle of the flue dividing it into two halves, the bottom half of which is unutilised. In this new system the bottom half of the flue is utilised by adopting a V-shaped formation of grate, as shown in Figs. 1 and 2, the bars ending in an open-topped channel into which is fitted an ash-extracting screw shown at A, which is so

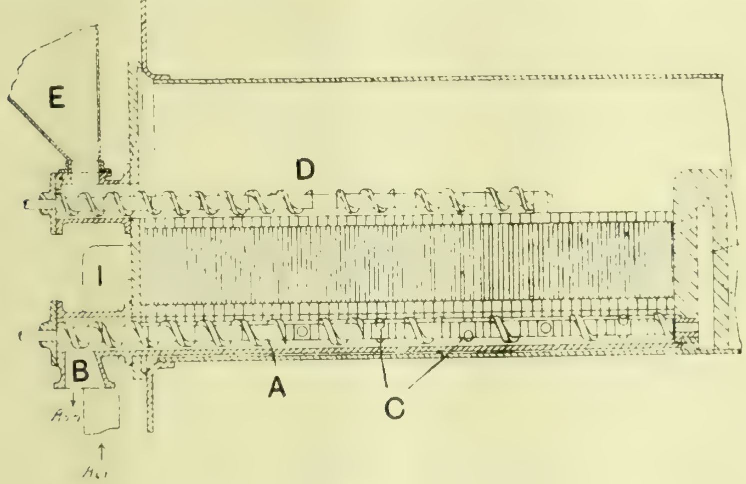


FIG. 1.

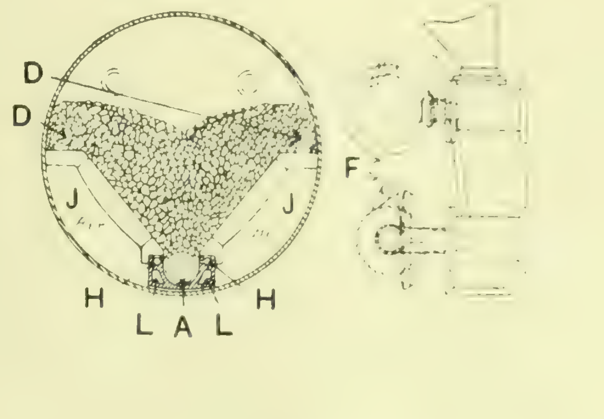


FIG. 2.

designed that it takes the ash uniformly throughout the length of the furnace and delivers same at the front of the boiler, as shown in Fig. 1 at B. This screw has also got clinker breakers attached to it, shown at C, which effectively break any clinker that may be formed, enabling it to be discharged by the carrying portions of the screw, which are built in sections on to a hexagonal central shaft, thus making this system very suitable for clinkering coal, due to the hottest zone always being in the centre of the furnace above the clinker breaker, and keeping the clinker from covering the bars and so choking the supply of air to the furnace. The nature of the fire in this system is more akin to a gas producer inside the flue with a deep, highly-incandescent mass of fuel giving the air a long time in contact with the fuel instead of a low temperature with a short time, as in an ordinary fire. The coal is fed into the furnace by two interrupted screws, shown at D, Figs. 1 and 2, from the hopper E, which screws are completely protected from overheating, due to the fact that they are always surrounded with black coal; these screws form an important feature of this system, because when the coal comes to an interruption in the thread, it naturally takes the easiest course of resistance, and so is squeezed towards the centre, and when the coal arrives at the point desired towards the centre of the furnace, the resistance becomes more, when that point is reached, than it takes to pass the coal along the interruption, when it is caught up by the next portion of the thread, and the same conditions maintain at the next interruption, and so on. By this means an ideal system of feed is obtained, referred to under heading (*c*); that is to say, no holes can form in the fire, because so soon as a hole starts to form, that automatically becomes the place where the most coal will be delivered. F on Fig. 2 represents the mechanism for driving the screws, which has a large variation of adjustment to suit different rates of steaming and different classes of coal. The ash-extracting screw is kept cool through allowing a small supply of water to pass along to the back end of the trough at the position marked H, Fig. 2, so that the ash is delivered in a damp condition at the front of the boiler. From a fan air is supplied through the ducts which passes in underneath the bars to the space J, and this can be regulated according to requirements. Auxiliary air may be passed through L up through the back wall as shown. The results obtained from this system, so far, are very encouraging, because a high coal efficiency, along with a high boiler efficiency, is obtained with complete smokelessness.

Referring to sources of loss under heading (*a*), (*b*), (*c*), and (*d*):—

(*a*) (*i.e.*, lost heat carried away in the gases passing up the chimney). This loss is reduced, because of the large amount of coal under combustion leading to much more heat obtained through radiation, resulting in the possibility of getting the boiler efficiency high, through burning a sufficient quantity of coal per square foot of grate area at a slow rate of burning per pound of coal without so much excess air to get this quantity burned per square foot, the reduction in the volume giving more time in contact with the heating surface.

(*b*) (*i.e.*, the loss due to incomplete combustion of the carbon in the fuel). Due to the centre of the furnace being always at a very high temperature and due to the air having to pass through a deep body of incandescent fuel, the temperatures are continuously much higher than in an ordinary fire, which gives a much better chance of complete combustion, and as the coal distils from the sides of the furnace around and above the feeding-in screws D continuously, this distillation or smoke is continually overcome by the high temperature flame bed, up the centre, hence this system is smokeless.

(*c*) The loss due to holes in the fire is eliminated as explained.

(*d*) The loss due to open doors while cleaning is also eliminated because there is no cleaning.

A further advantage of some importance is that, in a large range of boilers, it would be the natural thing to have an automatic coal feeding and ash removing system attached, in which case there would be only a supervisor for a range of boilers to look to adjustments. Many textile mills have economisers installed; where this is so, there is a higher economy than in installations which have no economisers, but, of course, if a better system of burning the coal could be obtained, so that more of the heat was got into the boiler, economisers would be unnecessary, and the maintenance and capital expenditure on them eliminated. This is certainly the right direction in which to work, because economisers at their best are only there as a result of inefficient furnace systems. Below I give the comparative tests carried out

recently on two Babcock boilers in a large works near Glasgow:—

	Hand Fired.	New System.	Hand Fired.	New System.
Date	15/1/13	24/3/13	28/1/13	4/4/13
Heating surface of boiler in square feet	1,260	1,260	1,260	1,260
Grate area in square feet	28·9	28·9	28·9	28·9
Gross weight of fuel used, in lbs.	6,363	4,514	8,848	6,988
Gross weight of fuel used per hour	795·37	564	1,106	873·5
Gross weight per square foot grate area	27·5	19·65	38·23	30·2
Total water used, in lbs.	25,800	28,780	39,495	41,131
Total water used, in lbs. per hour	3.225	3597·5	4936·91	5141·3
Total water used per square foot heating surface	2·56	2·85	3·91	4·08
Water to coal apparent	4·06	6·375	4·46	5·88
Water to coal (ash and moisture deducted)	5·44	8·07	5·98	7·17
Evaporation from and at 212 deg. (per lb. of combustible)	6·58	9·82	7·23	8·68
Factor of evaporation	1·216	1·217	1·216	1·214
Temperature of feed-water	40 deg. F.	40 deg. F.	40 deg. F.	44 deg. F.
Waste gases leaving boiler, average temperature	—	464 deg. F.	923 deg. F.	534 deg. F.
Average steam pressure, lbs. per square inch	91	93	92·6	99

Note.—Fuel weighed and water measured from tank.
Duration of test—8 hours.
Class of coal—Best washed singles.

In these works there are no economisers, and they require a high boiler efficiency, and you will see that the comparative results, under their old conditions of hand-firing against the new conditions, show an actual money saving of about 25 per cent., and this economy is established simultaneously with the elimination of smoke which, with hand-firing, was very black.

There is another important commercial factor which I should like to call attention to, namely, the B.Th.U. of heat in a cheap coal can be bought for much less money than in a dear coal. From recent figures quoted in Glasgow, I find that coal costing 4s. 3d. per ton contains 10,100 B.Th.U., whereas coal costing 17s. per ton contains 14,830 B.Th.U. Taking it roughly, and supposing these figures were 10,000 and 15,000 respectively, it works out, in this instance, that if we could utilise the heat units in the cheap fuel as efficiently as in the dear fuel, we should get per £1 with the cheap fuel what we would have to pay £2. 13s. 4d. for with the dear fuel, but in many cases (due more to mechanical difficulties than any other reason) it is impossible to get the required amount of steam from the cheaper fuel, and it seems clear that a better system of burning the coal will have a bearing on this aspect, because where a cheap fuel is being used with a large per cent. of ash, this means a continual loss in cleaning the fires, with a tendency to produce smoke when firing up after cleaning, which loss is eliminated with such a system as I have described. Further, if a system be adapted which increases the amount of coal under combustion to, say, twice the amount with ordinary systems, there would be as much fuel under combustion, with a coal containing 50 per cent. of ash, on this hypothesis, as there would be in the ordinary systems with an absolutely pure coal containing no ash, and hence it is clear that the output could be much more readily maintained with a system of this kind than with the orthodox system of fire. I was recently studying some figures of a large textile concern in Scotland, and in once case 54 per cent. of efficiency was obtained, while in the other 75 per cent. of efficiency was obtained, but when brought back to a money basis, the 54 per cent. was considerably more economical than the 75 per cent., due solely to the fact of the much lower cost per British thermal unit of heat in the low-grade fuel.

The foregoing seems to me to be the lines on which the presently-installed boiler systems may be made smokeless with a commercial gain.

Referring to second heading, the system of first producing gas from the coal, then firing the boilers with the gas, this method, which does away with the smoke nuisance, has advantages, but it would appear that, generally speaking, up till now the capital expenditure has been so high that this method does not come into the realm of practical politics for most commercial concerns. However, there are two new factors which will no doubt have an influence in bringing this system more prominently to the front for new concerns. Firstly, important developments are taking place in connection with the distillation of coal, more particularly from the point of view of the recently enhanced value of the by-products that can be obtained therefrom, namely, sulphate of ammonia and the lighter oils. It is rapidly becoming more generally recognised that coal contains extremely valuable by-products, and I think there is no doubt that there will be great advance made in methods of distillation increasing the per cent. of the more valuable by-products, such as benzol, for which there is a rapidly growing demand for internal-combustion engines, &c. The indications are that there is a big field for development in this direction which will have an influence on this method of first making gas and then firing the boilers with the gas. Secondly, the new system of firing boilers with gas recently discovered, and known as the Bonecourt system, for producing radiant heat by means of flameless incandescent surface combustion. This recent discovery enables gas to be burnt with the highest possible economy, and further leads to a radical reduction in the size of steam boilers, housing, space, &c., with a consequent saving in capital expenditure.

I should like to call attention briefly to the question of oil as a substitute for coal. We have heard a great deal during the last year on this subject, and I think there is no doubt but that this system will become more prominent in the future, but it will be a long time before oil will become in any sense a substitute for coal. On the authority of F. E. Saward, the eminent New York expert, in his report for 1912, the world's coal output for that year was 1,278,577,812 tons —figures which are very significant.

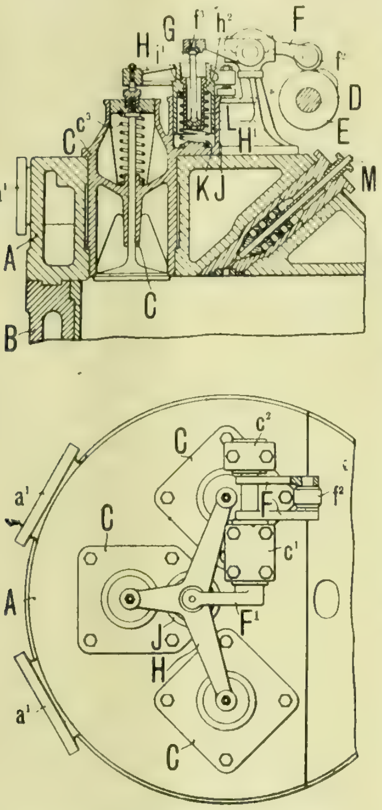
In conclusion, what I have said may give the impression that I have dealt more with questions of economy than of smoke consumption, but it has long been recognised that the smoke problem really resolves itself into an economic problem, and I hope the above analysis of what seems to me to be the necessary conditions to be complied with will at least help to stimulate thought on this subject, for when it pays to raise steam without smoke, the smoke will gradually disappear, a consummation so vital to the health of the people.

KRUPP'S VALVE GEAR FOR TWO-STROKE CYCLE INTERNAL-COMBUSTION ENGINES.

A DESIGN of valve gear for use with internal-combustion engines, the invention of Messrs. Fried. Krupp, of Kiel-Gaarden, Germany, is shown in the accompanying cuts. The gear is specially applicable to 2-stroke cycle internal-combustion engines in which several scavenging valves arranged in the cylinder cover are controlled from a common valve lever through a multiple-armed intermediate piece, the scavenging valves being so arranged as to leave a space free between them for the fuel valve. In an arrangement of this kind it is not always possible to allow the valve lever to bear exactly at the centre of gravity of the intermediate piece. If, however, this is not done, the unequal distribution of the masses readily causes the tilting of the intermediate piece upon pressure being applied thereto, and irregular operation of the several valves results in consequence. In the arrangement under notice, all the valves are operated uniformly.

In the cover A of the cylinder B are arranged three scavenging valves C, which open toward the interior of the cylinder and are connected by means of two branches a^1 to the main scavenging pipe. These scavenging valves C are operated conjointly, through a three-armed intermediate piece H, by a valve lever F F[1] acted upon by a disc E on a valve shaft D. The valve lever is cranked and is carried by bearings in two standards c^1 c^2 which are cast on to the casing of one of the scavenging valves C, which latter is arranged between the standards. The part F of the valve lever is fork-shaped and carries the valve bowl f^2. The intermediate

piece H is guided on a straight line by a hollow cylindrical extension H^1 in a part J of hollow cylindrical form, and rigidly connected to the cylinder cover. The arm F^1 of the valve lever bears upon the intermediate piece H through the medium of a thrust bar G having spherically-shaped ends, and a bucket-shaped sleeve L. This latter is inserted into an opening in the extension H^1 from above, and is supported by means of a flange i^1 upon an annular shoulder h^2. An abutment f^3 on the lever arm F^1 for one end of the thrust bar G is interchangeable and a similar abutment for the other end of the bar G forms the bottom of the sleeve L. A helical spring K surrounding the sleeve L serves to assist the valve springs c^3 of the scavenging valves. In the space between the three scavenging valves C' is obliquely inserted the fuel injecting valve M, which is operated from the valve shaft D by a cam disc (not shown).



KRUPP'S VALVE GEAR FOR INTERNAL-COMBUSTION ENGINES.

The action of the gear will be understood from the drawing, without further explanation. The straight guiding of the intermediate piece H ensures, in comparison with the known valve gears of the same kind, the advantage that no tilting of the intermediate piece and consequently no irregular operation of the three valves can take place, such as would most certainly occur without this guiding in the case where the intermediate piece H has unequal lengths of arms. Again, should it be desired, as is the case in the known valve gears, to allow the valve lever F F^1 to act on the intermediate piece directly from above, there would still always be the danger that the tendency to tilt which is inherent in the intermediate piece H, notwithstanding the straight guiding, might soon bring about a one-sided wear of the straight guide or even cause the part H^1 to become jammed in the part J of the guide. This danger is effectively obviated in the gear illustrated by the point of work transmission of the valve lever F F^1 being arranged very low, owing to the interposition of the thrust bar G. Should, in the course of time, wear arise between the valve lever and the intermediate piece H it can be easily compensated by renewing the abutment f^3 of the thrust bar G. The spring K assists the valve springs c^3 in their action by balancing the intermediate piece H, while this balancing simultaneously prevents the similarly acting valve springs c^3 from exerting any tilting action upon the intermediate piece when they expand, owing to the unequally distributed masses, which tilting action might likewise be manifested in one-sided wear of the straight guide or in jamming of its parts.

FLUXES FOR USE IN MELTING SOFT METALS.

WHEN the so-called soft metals, such as tin, lead, zinc, and their various alloys, are melted, the surface of the molten metal oxidises and produces what is known as "dross." Dross is the metallic oxide mixed with more or less metal. It is not all oxide as many persons believe, but the oxide becomes entangled in the metal itself, producing a mass which becomes thick and does not flow readily. It is the function of fluxes, when soft metals are melted, to act upon this dross (or in reality, the oxide in it) and clean and clear the surface of the metal. Those who are not familiar with the action of fluxes should try an experiment and be convinced of their value. Melt some lead and it will be noticed that the surface is covered with a film. If the lead is scrap material, then a greater quantity of dross will form for the reason that the scrap lead is already oxidised to some extent and this oxide floats on the surface of the metal. Now throw on a small piece of rosin. The rosin will immediately melt and clear the surface so that it will have a bright appearance and as clean as the surface of pure water. The rosin dissolves the oxide, forming a slag which floats to the side of the ladle in which the lead has been melted, and may readily be skimmed off.

The use of fluxes in melting soft metals is quite important, particularly when scrap metals are used, as they serve to cleanse the molten metal from oxide and produce clean, clear material that will readily run into moulds. Scrap metals, as a usual rule, melt with the formation of considerable dross, and if no flux is used on them, the bars of metal cast will not be clean. By the use of fluxes, however, it is possible to obtain nearly as clean metal as though new materials had been employed. The question as to what kind of flux to use in melting soft metals will depend upon the metal itself. The following directions, reproduced from "The Brass World," may, according to our contemporary, be safely followed:—

Tin and its Alloys.—This list comprises the solders, britannia-metal, block tin, babbitt-metals with a tin base and any other alloys of which tin is the principal constituent. For tin and its alloys, rosin is the best flux, as it requires but a small quantity on the surface after melting to clean it. Sal-ammoniac, too, is a good flux for tin and seems to work better if the metal is used quite hot; and at a temperature at which the rosin burns off. The rosin, however, is to be preferred, as it is free from the fumes of sal-ammoniac.

Lead and its Alloys.—This class comprises some of the solders, which contain lead in excess, babbitt-metals with a lead base, pewters, and the various antimonial-lead alloys, together with pure lead itself, and other various alloys containing lead as the principal ingredient. For lead and its alloys, rosin is the best flux. It acts in a manner similar to that of tin and at once clears the surface. Sal-ammoniac does not work well on lead or its alloys unless quite hot and then it seems to have a good effect. This action, however, is not satisfactory when the lead is at the heat ordinarily used for pouring metals, and the temperature at which it does act is so high that it is rarely employed in practice. The rosin, therefore, is the best flux for use in melting lead and its alloys.

Zinc and its Alloys.—There are but few zinc alloys used, of which zinc is the principal constituent, and one of the chief components of this class is the well-known die castings. The white brasses (some of the white brasses contain tin as the principal ingredient) are also made with zinc as the chief constituent. Zinc itself, however, is extensively used. The best and in fact the only flux that can be used on zinc and its alloys is sal-ammoniac. This has an excellent cleansing action and produces clear, clean metal from that which is quite dirty. Rosin is not suitable for use on zinc and its alloys, and although it has some cleansing action, it is not satisfactory. Sal-ammoniac, however, seems to give all that is desired in the way of a flux for zinc and its alloys.

The manner of using the fluxes is simple. After the metal is melted, whatever it may be, tin, lead, or zinc, or their alloys, the flux is thrown on the surface and stirred in. No particular amount of flux can be given for use, as it will depend upon the amount of dross to be cleaned from the surface. The way to do is to throw on a small quantity of the flux, stir and skim off the dross as clean as possible. Then add more, if required, until the surface is clean. By adding the flux little by little, instead of a large quantity at one time, the progress can be watched, and it is not wasted for the reason that only just enough is used to clean the metal. The fluxes are always used on the surface after the metal is melted, and are not put in while the melting is taking place.

Institution of Naval Architects.—The Council of this Institution have accepted an invitation to hold a summer meeting in Glasgow, June 24th to 27th, which has been extended to the Institution by the President and Council of the Institution of Engineers and Shipbuilders in Scotland. Meetings for the reading of papers will be held in the Scottish Institution's building, and arrangements will be made to visit some of the principal works in Glasgow and its vicinity. An influential reception committee is being formed under the chairmanship of the Rt. Hon. Lord Inverclyde.

CLEANING BLASTFURNACE AND OTHER GASES.

AT a meeting of the Cleveland Institution of Engineers held on April 7th an interesting paper, entitled "Modern Practice in Cleaning Blastfurnace and other Gases," was read by Mr. H. Stonewall Jackson. Whether it was blastfurnace, producer, or coke-oven gas which was used, purity was, he observed, an important factor, especially for gas engines, but with the ever-increasing means of using moderately clean gas, many forms of what might be termed "pre-cleaners" had been devised. Probably the most usual methods adopted for this preliminary cleaning, in addition to the ordinary downcomers, took the form of vertical cylindrical towers made of steel plates, worked singly or in series according to the dust contents of the gas. The Zschocke type was perhaps the most popular, and good work was being done by this type of cleaning tower at the works of the Skinningrove Iron Company, Ltd., Skinningrove. The towers were two in number, arranged to work in series, each 19ft. 6in. diam. by 38ft. high, and each containing four sets of wood hurdles placed about 6ft. apart, the laths forming the hurdles being of 3½in. by ½in. section and placed 3in. apart. On the top of each tower were placed 21 sprinklers with special nozzles so arranged that the cleaning water was sprayed over the full area in the form of a fine spray or vapour. The gas entering the bottom of one of the towers emerged at the top partly clean, and passed down a vertical pipe to the bottom of the second tower, and then out of the top as before. The bottom of each tower was cone-shaped and water-sealed, and the collected dust falling to the bottom of the water seal could easily be drawn away. The incoming gas had a temperature in this particular case of about 200° Fah., and the temperature of the gas leaving the second tower was about 70° Fah., the dust in the incoming and outgoing gas being approximately 6 grammes down to about 0·5 gramme per cubic metre respectively. The gas at this stage was used for the boilers and stoves, but a portion of the gas was further cleaned to 0·02 gramme by means of Theisen washers for use in gas engines.

At the works of the Société Anonyme John Cockerill, Seraing, an installation of two Zschocke washers, capable of cleaning 40,000 cubic metres of gas per hour, was at work. Each tower was 17ft. diam. by 75ft. high, and the gas passed through the usual arrangement of dust catchers before passing into the washers. The author gave the following particulars of two tests taken when the furnaces were working on different iron:—

Temperature of gas at inlet	100/150° C.	250/300° C.
Power required per 1,000 cub. m.	2·96 kw.	4·87 kw.
Water required per 1,000 cub. m.	5·19 c.m.	10·73 c.m.
Dust per cub. m. entering	3 to 4 grms.	2 to 2·5 grms.
Dust per cub. m. leaving	0·40 grm.	0·35 grm.

With this system of cleaning very little power was required, but even for heating purposes it was now recognised that a higher degree of purity was an advantage, hence the adoption of rotary washers.

The Bian gas washer was, he stated, a very simple and fairly efficient apparatus, and consisted of a horizontal cylindrical chamber in which were a number of screens carried on a revolving central shaft. The gas entered the apparatus at the top at one end and left at the top at the opposite end; the dust was caught by the revolving screens, which were washed by the water in the bottom portion of the chamber, and was carried away with the dirty water. The shaft carrying the screens revolved slowly, and consequently the power absorbed was small. Another form of rotary washer dealt with by the author was the Fowler-Medley vertical gas washer. It comprised a circular cast-iron casing, in the centre of which was revolved a vertical shaft, to which were fixed a number of flat circular discs, separated from each other by collars. Two fine jets of water diametrically opposite each other were projected between each pair of discs. These jets struck on the separating collars, and thence splashed on to the opposite surface of the discs, which as they revolved flung the water off from their peripheries across the annular space between them and the casing in the form of a rapidly moving and finely divided spray. The gas entered the washer below the revolving discs, passed through the spray-swept space surrounding them, and left above the discs. These machines were economical in power and in water: for rough cleaning from 6 grammes to 0·3 gramme per cubic metre dust content, about 90 galls. of water per minute with 10 h.p. were required, and for fine cleaning down to 0·02 gramme per cubic metre dust content, a second machine was installed in series with the first, using 50 galls. of water per minute and 6 h.p. for 250,000 cub. ft. of gas per hour.

The system of gas cleaning by means of fans had been successfully applied at the works of Alfred Hickman, Ltd., Bilston, where about 1,000,000 cub. ft. of gas per hour was cleaned. The plant comprised a set of three fans, each 4ft. diam., working in series and in parallel with a Theisen washer. The gas, after passing through this plant, was dealt with by two sets of fans, each 66in. diam., working in series with two similar sets in parallel. The water used was canal water, of which an unlimited supply was available, so that the 7,000 galls. to 10,000 galls. used by each fan per hour was not of much moment. The reduction in dust content was from 3 to 7 grammes down to 0·02 gramme per cubic metre.

The blastfurnace gas-cleaning plant at the works of the Frodingham Iron and Steel Company, Ltd., Scunthorpe, consisted of Zschocke scrubbers working in series with Theisen washers. A recent test of this plant with one Zschocke scrubber and one No. 4A Theisen washer, working in series and supplying gas to three generator engines and three blowing engines of an aggregate of 4,750 h.p., gave the following results, the atmospheric temperature being at the time 20° C., and the volume of gas cleaned being 7,800 cub. ft. per minute:

	Gas. Deg. C.	Water. Deg. C.
Temperature entering Zschocke scrubber	82	23
Temperature leaving Zschocke scrubber	23	37
Temperature entering Theisen washer ..	23	23
Temperature leaving Theisen washer ..	23½	24
Cooling water to Zschocke washer	240 galls. per min.	
Cooling water to Theisen washer	130 galls. per min.	
Dust in gas entering Zschocke scrubbers	8·42 grms. per c.m.	
Dust in gas entering Theisen washer	3·83 grms. per c m.	
Dust in gas leaving Theisen washer	0·023 grm. per c.m.	

The power absorbed by the Theisen washer on the above test was 490 amperes at 220 volts.

To meet the demands of modern plants and to enable the waste gases to be utilised to the fullest extent, Theisen had evolved a new invention in the form of a combined disintegrating gas washer which used less power and water. The leading features were that the cooling, cleaning, and production of pressure were done in the one apparatus with only one drive, while a small amount of power was required, and only 0·11 gall. to 0·16 gall. of water per cubic metre of gas was necessary. The degree of purity was constant and uniform for engines at 0·01 gramme per cubic metre, and for stoves, boilers, &c., at 0·1 to 0·2 gramme per cubic metre, and this without any pre-cleaning. The space occupied was small, and the apparatus was simple and required little attention when at work.

Dealing with blastfurnace gas, the temperature of which—when no preliminary cleaning was adopted—on arrival at the gas-cleaning plant was usually about 100° to 130° C., these hot gases were first brought into contact with the main volume of the water sprayed out by the disintegrator arrangement, thus giving a preliminary cooling and cleaning of the gas in the bottom of the apparatus. The gas then passed through the disintegrator, which consisted of partly rotating and partly stationary perforated drums arranged concentrically in one another. By means of the centrifugal action of the rotating drum the washing water was beaten into vapour or fine spray and thoroughly mixed with the gases, the particles of dust saturated with vapour thereby passing into the washing water and being thrown out with the latter. The fan built inside the apparatus had blades so formed that they threw out the still wet gas laterally on to a washing plane built concentrically round the fan blades. By this means the water thrown out of the gas formed on the conical washing plane a sheet of water which circulated outwardly and caught the last solid particles still contained in the gas as it passed over. As the whole of the water as well as the gas were thus intensively mixed one with the other into the finest spray, the utmost value was made of the washing water. In consequence of the intensive wash-

ing and rinsing of all parts of the apparatus, it was impossible for them to become encrusted, and therefore an uninterrupted service was assured. It was unavoidable, owing to the extreme action of the apparatus on the washing water, that some vapour might be carried away with the cleansed gas; therefore it was usual to install a vapour separator immediately behind the washer, thus ensuring gas being delivered in a dry condition.

Two of these Theisen disintegrating gas washers had, the author mentioned, been at work at Haspe for some months, cleaning blastfurnace gas without the interposition of any preliminary cleaners from 6 grammes down to 0·016 gramme per cubic metre. At Gladbach, one of these machines was cleaning 6,000 cub. ft. per minute of blastfurnace gas from 4 grammes down to 0·031 gramme per cubic metre with 45 galls. of water per minute, the power absorbed being 40 h.p. At Maximilianshütte, Unterwellenhorn, one of these machines was dealing with 6,400 cubic metres of blastfurnace gas per hour, used for fuel purposes, and cleansing same from 4 to 6 grammes of dust per cubic metre down to 0·3 to 0·4 gramme, the power consumption being 19 kw. This washer was also designed to cleanse the tar from coal-fired blastfurnace gas, which was the principal ingredient to be dealt with in the gas from this type of blastfurnace after it had passed through a recovery plant.

For extracting the tar from coal-fired blastfurnace gas the Summerlee apparatus was, he remarked, very efficient. The apparatus consisted of a chamber made of steel plates fitted with a number of trays or nests of specially-designed valves placed one over the other. The gas entered the bottom of the chamber, and in passing through the valves the tar was caught by the special lip formed by the valve and its hood and collected on the trays, from which it was drawn away. So free was the gas emerging from the top of the apparatus that the gas engines supplied with this gas could run for months without the necessity of stopping to clean valves. Another efficient appliance was, he said, the Crossley centrifugal tar extractor, designed for dealing not only with blastfurnace gas, but with producer gas from bituminous fuels for driving gas engines and also for fuel purposes. It also dealt with water gas in gasworks, coke-oven gas, and a number of special chemical installations, such as sulphur extraction. These extractors were made both on the single and double stage principle, the latter having two impellers fixed on one shaft. The gas was led to the centre of the impeller on the inlet side, and was thrown to the periphery of the impeller by means of blades riveted on each side of the impeller disc. From the periphery the gas was constrained to pass to the centre on the outlet side. In this way the energy imparted to the gas on the inlet side was given back to the blades on the outlet side, the result being that the water-gauge pressure or vacuum was exactly the same on both inlet and outlet. Water was led by means of syphon pipes to the centre of the extractor on each side, and was spread by means of the impeller blades and driven from the periphery of the impeller. The path of the gas was therefore at right angles to this film of water driven off at a high velocity against the casing of the extractor. The very intimate diffusion of the gas and water, and the impact obtained from the water moving at such a high velocity, produced a thoroughly clean gas free from tar. To obtain the best results it was necessary that the gas before entering the extractor should be cooled to approximately atmospheric temperature. There was no pressure imparted to the gas, so that the power required to drive these extractors was small.

The author next referred to the Mond system of cleaning producer gas, as manufactured by the Power Gas Corporation, Ltd., as simple and efficient. The gas on leaving the producer entered a mechanical washer which consisted of a rectangular chamber, in which the gas was thoroughly washed with water thrown up into a fine spray by a system of rapidly revolving dashers. In this washer the gas was freed from all dirt and a large part of its tar, whilst its temperature was also considerably reduced. The dust and tar were removed by means of water-sealed cleaning lutes. From the mechanical washer the gas was led through fans arranged in series, the gas entering the fans at the centre and delivering at the periphery. Each fan was provided with water jets entering at the centre, and the spraying of same further cooled and cleansed the gas, which was then passed through a cyclone, where the gas, owing to the scrubbing action set up, due merely to the velocity and change of direction, was further cleansed. From the cyclone the gas was then passed through a sawdust scrubber for the final cleaning. On a Mond plant in use at the works of Richardsons, Westgarth, & Co., Ltd., the efficiency of the cleaning plant was such that no tar troubles were experienced on the gas engine; indeed, the gas was so free from impurities before reaching the sawdust scrubbers, the final stage, that it was found only necessary to change the sawdust trays every four months. With this plant, when cleaning 10,000 cub. ft. of gas per hour, only 2,000 galls. of water per hour was used, and as this water was passed through settling tanks and used over and over again, the loss was that due only to radiation and evaporation. The temperature of the clean gas was about 20° C., and the power absorbed by the mechanical washer and fans was 12 h.p.

The most recent inventions for cleaning blastfurnace gas were on the dry system. The Flossel centrifugal system was fully explained by Mr. Henry Crowe in his presidential address before this Institution a few months ago, but this paper would not be complete without mention being made of the Halberg-Beth process, descriptions of which have appeared in the technical Press. The author referred to a plant installed on this system at the works of Bell Bros., Port Clarence, of 10,000 cubic metres capacity per hour, which reduced the dust content from 5 to 6 grammes down to 0·012 gramme per cubic metre, the power absorbed by the fan being about 30 h.p.

POWER TRANSMISSION IN MINES.

A JOINT general meeting of the West of Scotland branch of the Association of Mining Electrical Engineers and the Scottish branch of the National Association of Colliery Managers was held on Saturday last in the Royal Technical College, Glasgow, when a paper by Mr. W. H. Telfer, general manager of the Wilsons and Clyde Coal Company, on "Power Transmission in Mines," was read and discussed. At the outset the author said that producing, transmitting, and applying power were at the present time very important factors in the economical development and working of mines, and as we went on the successful working of mineral fields would more than ever be dependent on transmitted power. Compared with 30 years ago the conditions of mining had very materially altered. Deep workings, large areas, capital involved, thin seams, cost and scarcity of labour, together with the value of fuel, were the points which had gradually been bringing to the front and impressing on the management of collieries the importance of generating, transmitting, and applying power by the most approved methods for the safe, reliable, and economical operation of all classes of mining machinery. Proceeding, Mr. Telfer went on to say that 30 years ago electricity had barely entered the field of mining operations, and mining people were then relying on their old and well-tried friends—steam, compressed air, &c. These, even with their drawbacks, had rendered invaluable service and had done good work in mining. Nevertheless there was no doubt that transmission of power by electricity easily took the premier place. Its adoption was gradually becoming more widespread and was cutting out to a large extent the older methods. Speaking generally, fairly large collieries or groups of collieries requiring generating plant of 400 kw. and upwards ought to have their own plant. If it were put down on the most modern lines, there was no reason why the current should not be produced cheaper than it could be got from a power company. With regard to collieries requiring between 200 kw. and 400 kw. plant, various points had to be considered before deciding which method was preferable. Where there was a sufficient supply of water for condensing without introducing cooling plant, and where steam was raised on the best lines and the load factor was fairly good, he still thought current could be produced cheaper than it could be bought from a power company. Although up to the present time they had had very few cases of fires in mines caused by electricity, he (Mr. Telfer) personally considered that if proper precautions were not taken it was a more likely cause of danger in our Scottish mines than ignition of gas and dust

THE STROBOSCOPE IN SPEED MEASUREMENTS AND OTHER ENGINEERING TESTS.*

BY PROF. DAVID ROBERTSON, D.SC.

General Principles Under ordinary circumstances, on looking at an object while it is in rapid motion nothing can be seen but a blur, but if vision be permitted only in periodic glimpses one is able to distinguish the object in a number of separate positions, and the appearance is that of a number of objects instead of only one. If the motion be a periodic one, and the glimpses be so timed that the cycle is seen in the same phase on each occasion, the object will appear to be stationary owing to the persistence of vision. If the glimpse frequency be a little lower than this, successive cycles will be seen at slightly later phases, and the appearance is that of the cycle performed slowly with a frequency equal to the difference between the actual frequency and the glimpse frequency. A similar result follows when the glimpse frequency is rather high, but the cycle is then seen backwards. Cinematograph films are obtained by giving a camera such intermittent views of the scene being photographed, each picture being taken on a separate part of the film. The resultant positive films are shown on the screen in a similar intermittent fashion, giving a continuous impression owing to the persistence of vision. They often show curious stroboscopic effects of the kind under discussion. Thus, the wheels of a carriage are seldom shown rotating at their proper rate; they often appear to be at rest

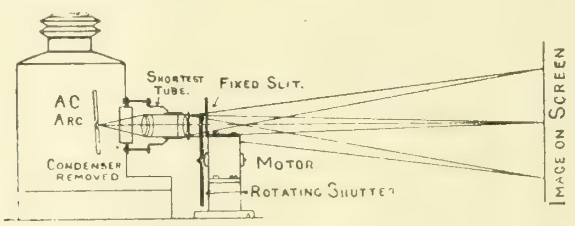


FIG. 1.—STROBOSCOPIC DEMONSTRATION OF AN A.C. ARC.

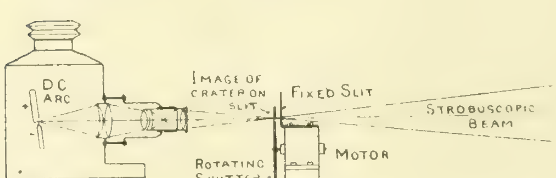


FIG. 2.—ARRANGEMENTS FOR STROBOSCOPIC BEAM.

while the carriage is in motion, and not infrequently they can be seen revolving the wrong way round.

The intermittency may be obtained either by periodically intercepting the line of vision, or by periodically extinguishing, or even varying, the illumination falling on the object. Intermittent illumination is generally more satisfactory than the other method. It is less trying to the eyes, it enables the phenomena to be seen by a number of persons at one time, and it often permits a closer examination. It is not necessary that the interrupted illumination should be the only one falling on the object, but it must be an appreciable fraction of the total.

Study of Periodic Phenomena.—By means of a rotating shutter, with a suitable number of slits and a fixed slit or eyepiece to limit the rays which can pass through, the changes in any alternating source of light, such as an alternating current arc or incandescent lamp, or a mercury vapour rectifier, can easily be studied. They may either be observed directly through the shutter, using an absorbing glass or polarising eyepiece if necessary, or an image can be projected through the shutter on to a screen or photographic plate. If the motor be a synchronous one driven from the same supply, and there be one slit for each pair of poles, the cycle will always be seen in the same phase, which can be varied by swinging the stator of the motor, or by changing the point on the circumference at which the light gets through. This arrangement would be used for photographing, and has also been employed with a photometer for measuring the variations of light, one method having two discs, of which one gives a fixed point on the cycle, to be used as a standard. If the driving motor be an induction one supplied from the same mains or a continuous-current one running just under synchronous speed, the cycle will be seen being performed slowly at the slip frequency. This is the best way for demonstration purposes, and the experiment is a very effective one with an alternating-current arc. The flame can be watched growing and contracting with the current, and the change of polarity of the carbons is easily followed if a magnet pole be placed behind the arc. Fig. 1 shows the arrangements for showing this experiment.

Very important information as to the running of fast machinery can often be obtained by examining it when illuminated by a stroboscopic beam, whose frequency is slightly different from that of the machine. A suitable beam can be obtained in the manner shown in Fig. 2. Such things as the way in which the rotating parts vibrate from want of balance, the position of the fault, the torsional oscillations of running shafts, the meshing of toothed gears, the action of cams, the whipping of shafts, and, in fact, any kind of quick vibration can be studied in this way. It has been applied to the photography of the water streams produced by screw propellers, to the study of the internal conditions in an engine cylinder at particular parts of the stroke, to the measurement of the relative angular displacement of two discs on a calibrated shaft in the "flashlight" torsion meter, to the elimination of cord errors in indicators, to the measurement of speed, and of speed fluctuations, and to many other purposes.

Another method of obtaining intermittent illumination which is sometimes useful is to employ a periodic electric spark. The sparks obtained at the brushes of a dynamo, for instance, when sufficiently bright show up the segments and lugs as if the machine were at rest.

Measurement of Speed by Auxiliary Motor.—The ordinary speed indicators and revolution counters cannot be applied beyond a certain speed, and in other cases they are inadmissible, as in making brake tests of very small motors, because of the error caused by their power absorption. In such a case the counter or indicator can be driven by an auxiliary motor, and the stroboscopic shutter and disc, one on each shaft, used to show when they are running at equal speeds, or when their speeds have a known ratio. The shutter would then be used in one of the ways already described, and the ratio of the speeds would be given by the inverse ratio of the number of slits and marks.

Schillo has used a rather different method when testing a turbine running up to 20,000 revs. per minute. The shafts are placed in line, with their ends close together; the end of one carries a stroboscopic shutter with one slit, and the other a disc with one radial mark. The arrangement is viewed from a sufficient distance to enable the mark to be seen through the slit whenever they come together, at whatever part of the revolution that may be. When the shafts rotate at equal speeds in opposite ways the slit and mark will pass one another every half revolution and always on the same two radii, consequently two marks are seen, fixed in space when the auxiliary motor runs at the the exact speed. When the one speed is twice the other, the encounters will occur every two-thirds of a turn, and a three-ray star will be seen, and so on for other multiples, which can, therefore, be recognised. When the two shafts revolve in the same way the number of rays visible on the star is one less instead of one more than the number of times one speed contains the other.

Tuning Fork for Standard Glimpse Frequency—If the glimpses be obtained by means of a vibrating shutter fixed on the prongs of a large tuning fork the frequency is constant, and gives a standard with which the speed desired can be compared. The frequency of such a fork is permanent, and can be relied upon to a very high degree of accuracy; its temperature change is very small. Rayleigh* quotes M'Leod and Clark, who give the frequency-temperature coefficient of a tuning fork as −110 millionths per centigrade degree; hence an accuracy of one in a thousand is obtained without making any allowance for ordinary room variations of temperature. The frequency diminishes very slightly when the amplitude is very

* Paper presented before the Institution of Engineers and Shipbuilders in Scotland, March 18th, 1913.

* "Theory of Sound." Vol. I, page 60. London: MacMillan & Co., 1894.

great, but with moderate amplitudes the change is imperceptible. It is quite possible to always work with the same amplitude, an easily recognised one being that which makes the apparent thickness of the tip of the prong twice its actual thickness.

This method is specially suitable for recognising certain fixed speeds: the slightest deviation from these speeds can be detected by the motion of the stroboscopic pattern. It is

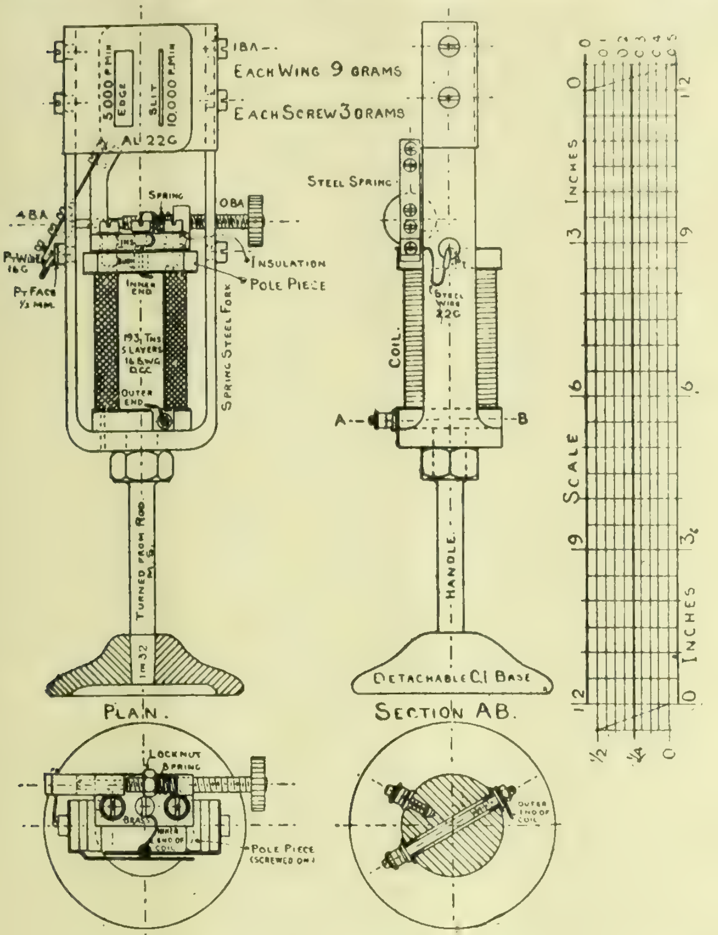


Fig. 3.—Details of Robertson Tuning Fork for Speed Measurements.

thus most useful for constant-speed work and for tests by the running-down method, for which it is not only more accurate, but also more easily applied than the ordinary methods. One industrial use to which the author believes it could be applied with a very great money saving is in the adjustment of electric meters in the factory or station test room. Instead of having to spend 30 seconds or more in taking the speed with a stop-watch after each alteration in the adjustments, a glance would suffice to show whether the speed was fast or slow and whether it lay within the permissible limits. All that would be necessary would be to have a suitable pattern on the brake disc of the meter, say, 98, 100, and 102 toothed rings, of which one is steady at the correct speed, another at the maximum, and the third at the minimum permissible speeds. The same pattern would also do for tests at $\frac{1}{2}$, $\frac{1}{4}$, and other loads. A standard pattern would be suitable for all meters of similar speeds, even although their correct speeds are not identical. Instead of testing them at exactly full load, the load would be set to that which ought to give the standard speed. So far as the author knows, this method has not been put into use in any factory.

The stroboscopic method of measuring speed has been known for a very long time in physics, being there generally used for the determination of the frequency. It has been strongly advocated for a number of years by Dr. C. V. Drysdale. The author has himself employed it in every-day use for over 10 years. Drysdale has designed a fork for the purpose, and the author has also produced one which avoids certain disadvantages common to those usually found in a physical laboratory. Fig. 3 shows the author's fork, which has a frequency of 83·33 per second. It can either be held in the hand, without the base, for direct vision, or stand on a table for intermittent illumination. It is driven by two storage cells, to which it is connected by a flexible wire and it is started by gradually turning the screw until the contacts touch, and stopped by screwing in the opposite way. The amplitude is adjusted by the same screw, and can easily be made very small or very large. The interrupter is as a rule the most troublesome part in the common patterns. Mercury contacts are generally used in forks for physical work, and have the advantage that they damp the motion less than solid contacts. But mercury is very inconvenient for general work, as it restricts the use of the fork. Most of those which have solid contacts have a springy wire attached to one prong and a contact block attached somehow to the frame. This arrangement is reversed in the author's fork, in which the natural frequency of the springy contact must exceed that of the fork, or it will not run properly. Nothing but platinum will do for the actual contacts. Difficulties arise from soldered joints on the spring wire, which should be of steel, and so the author puts a nick in the end of it, tins it, lets it into a hole in the end of a short piece of thick platinum wire, rivets it there, and heats it to sweat the two together. This arrangement has been found to stand being made red hot, due to accidentally making the contact so tight as to stop the fork, without damage.

Kennelly & Whiting use a fork, the prongs of which are loaded by sliding weights. These can be adjusted while the fork is running, and a scale is provided on which the exact frequency can be read. The change of frequency which can be produced in this way is not very great, but it is sufficient to bridge the gap from one synchronous speed to another, and so makes the speed range continuous.

The edge of the prong may be used as a shutter, but it is better to attach aluminium wings to the prongs, which open and close the path of the light as they vibrate. The fork must, of course, be standardised with these wings in place. Two methods can be distinguished, "edge" vision and "slit" vision. In the former, the path is normally closed, but is opened when the displacement is great enough in one direction. For the latter method, slits in the two wings are exactly opposite to one another when the prongs are at rest, but are closed when the displacement of each prong is half the width of the slit. Edge vision is obtained with the slits when the amplitude is too small to close them, and may also be got if they are not put opposite to one another. Edge vision gives an opening at each extreme of positive displacement, while slit vision gives one each time the prongs pass their equilibrium position. Consequently, the glimpse frequency with edge vision is the same as that of the fork, but with slit vision it is twice as much. It is convenient to arrange the wings with an opening for each method, so that two frequencies are available, as is shown in Fig. 3. Care should be taken that the slits for slit vision are accurately placed, otherwise the interval between the odd and even glimpses will not be the same as that between the even and odd ones, and the result will be a distortion of some of the patterns.

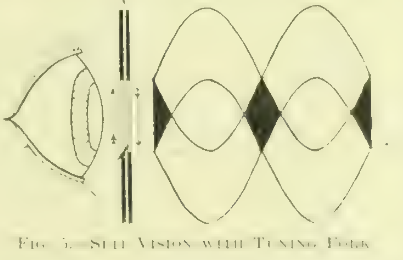


Fig. 4.—Edge Vision with Tuning Fork.

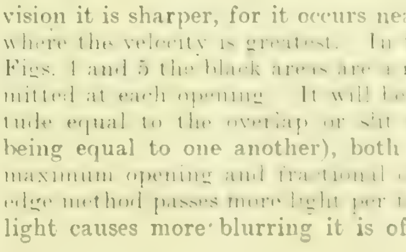


Fig. 5.—Slit Vision with Tuning Fork.

With edge vision, cut-off takes place while the prongs are moving slowly near the extremes of their swing. With slit vision it is sharper, for it occurs near the middle of the swing where the velocity is greatest. In the displacement curves of Figs. 4 and 5 the black areas are a measure of the light transmitted at each opening. It will be seen that with the amplitude equal to the overlap or slit width, respectively (these being equal to one another), both methods give the same maximum opening and fractional duration of glimpse. The edge method passes more light per fork cycle, but as this extra light causes more blurring it is of little value. With edge

vision the amount of light passing increases, and the sharpness diminishes as the amplitude is made greater. With slit vision the reverse is true. If a very sharp cut-off, combined with a large illumination or small amplitude be required, it can be obtained by making each wing with a grid on the principle of the multiple-ported slide valve, as shown in Fig. 6. All the slits must open and close together, and the source of light must be big enough for its image to cover all the openings at once. The eye would hardly be able to use more than one slit at a time, and so the device would be of little use for direct vision. By using more elaborate optical arrangements it is possible to attain the same end with a single slit.

The best frequency of the fork depends on the speed to be measured. The higher the frequency, the greater is the number of recognisable speeds between any two given ones, because of the greater number of marks required on the stroboscopic pattern. Thus, if one fork requires 10 rays and another 5 for the same speed, there might also be rings with 9 and 11, a difference of 10 per cent. on the former, whereas the next numbers for the latter are 4 and 6, a difference of 20 per cent. On the other hand, as will be seen from the equations given later, the apparent motion of the rays with a given difference between the synchronous and actual speeds is proportional to the fork frequency; consequently, the higher the frequency of the fork, the smaller the range of speed over which the pattern can be timed and detected, and the more difficult it becomes to find it when adjusting the speed. Where the marks have to be specially made for each experiment, a high fork frequency has the further disadvantage that it requires a larger number to be set out. Another point is that forks of high frequency are of necessity short and can only have small amplitudes, requiring narrow slits and so passing little light. This is, however, to some extent balanced by the greater frequency of the glimpses. Drysdale uses a fork giving 50 cycles per second. The one used for many years in the author's laboratory at the Merchant Venturers' Technical College, Bristol, is the largest of a set obtained for showing Lissajou's figures, and has a frequency of 128 per second with the attachments required for that purpose. As now used for speed work with the weights removed and the wings added, its frequency is 140·4 per second, giving glimpse frequencies of 8,424 and 16,848 per minute. Its prongs are 174 mm. long, 14 wide, and 5½ thick, and it easily gives double amplitude of 5½ mm., which is the one generally employed. For the experiments referred to below the slit was about 2·2 mm. wide.

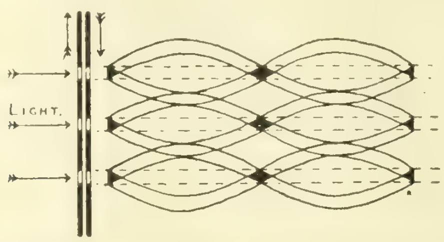


Fig. 6. Grids for Large Opening with Small Amplitude.

The author's new fork gives 5,000 and 10,000 glimpses per minute. Probably 6,000 and 12,000 would be a very convenient standard, as it would give a number of synchronous speeds at exact hundreds per minute. For very high-speed work, say above 2,000 revs. per minute, a higher fork frequency might be desirable in order to have more speeds available, and for such low speeds as occur in electric meters a lower frequency is to be preferred.

Instead of controlling the flow of light directly by the tuning fork, the latter may be made to control a small phonic wheel motor to which a revolving shutter is attached. In this way a large amount of light can be passed with a short glimpse, and the glimpse frequency can be made any desirable simple multiple or sub-multiple of that of the fork, by a suitable choice of the number of projections on the motor wheel and of slits in the shutter. But the chief advantage of this arrangement is that it enables a continuous scale to be obtained by driving the shutter through a cone friction gear, by which its speed may be varied sufficiently to bring the glimpse frequency into synchronism with the stroboscopic pattern on the shaft whose speed is required. This device has been proposed by Drysdale, but there is some difficulty with the motor drive. The arm carrying the pivot bearings for the shutter disc can be moved along by a screw so as to alter the position of contact on the cone until the desired speed is obtained. The speed ratio is proportional to the distance of the point of contact from the vertex of the cone, and is marked once for all on the scale, which is thus a uniform one. The points of equal ratio, or other simple values can be easily checked by observing through the shutter a suitable pattern rotating with the cone (*e.g.*, the teeth of the motor). If the number of marks be the same as that of slits, the pattern will be steady when the speeds are alike or bear a simple ratio to one another. Dr. Drysdale states that this arrangement of disc and cone never gives any trouble from slipping if the adjustment is right.

Actions Near Primary Speed.—For the measurement of speed it is necessary, as a rule, to observe a row of similar and equally spaced spots or marks placed around a rotating disc or pulley. Let the speed be such that during the interval between successive glimpses the marks move one place forward (see Fig. 7). Each spot will then be in the position which was occupied at the previous glimpse by the one ahead, but, owing to the persistence of the impression on the eye and to the fact that all the marks are alike, it will seem as if no motion had taken place. The result is that the whole set can be seen, although they are actually in rapid motion, and they appear to be stationary. This may be termed the primary speed to distinguish it from the other synchronous speeds to be referred to below. The motion of the spots during the time they are

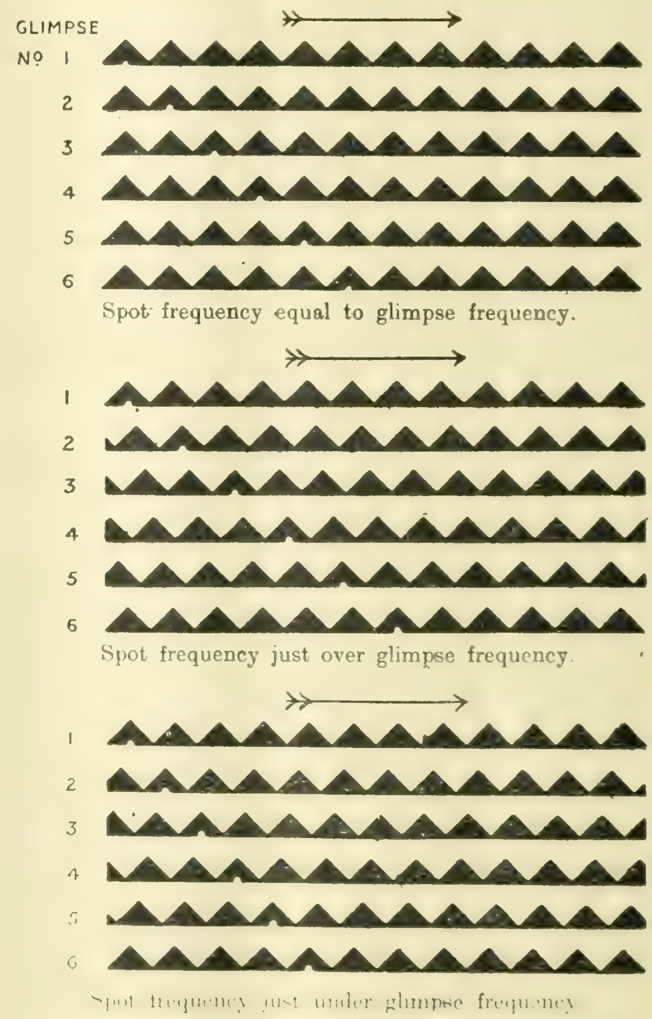


Fig. 7. Actions Near Primary Speed. One Mark is Notched to Show the Actual Motion.

actually visible causes a certain amount of drawing out and loss of distinctness of the images, but this can be reduced as much as desired, at the expense of brightness, however, by making the duration of each glimpse a sufficiently small fraction of the time between them.

Should the speed be a little above synchronism, the spots

will reach a little further than the next place by the second glimpse, but, owing to the same cause which formerly made them appear to be stationary, the eye will get the impression that each has only moved a distance equal to the excess of their motion over their distance apart. The result is that the whole set can be seen moving slowly forward with a velocity equal to the excess of their speed above synchronism. If the speed be a trifle low, there will be a small deficiency of displacement each glimpse period, and the spots are seen to be moving slowly backwards with a speed equal to the defect from synchronism. It is easily seen from Fig. 7 that in either case the apparent velocity is obtained by subtracting the synchronous speed from the actual one.

Let f_g = frequency of the glimpses.
f_s = apparent frequency with which spots pass a fixed point, taken as negative when they go backwards.
N = speed of shaft.
N_0 = synchronous ditto = $f_g \div n$.
n = number of equi-distant similar marks round the circumference.

$$\text{Then, } f_s = Nn - f_g = n\,(N - N_0) = \frac{N - N_0}{N_0} f_g \quad . \quad . \quad . \quad (1)$$

$$\text{And, } N = \frac{f_g + f_s}{n} = N_0 + f_s / n \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Equation (1) shows that the slip is the same for the same proportional error in the speed, whether high speeds and few spots, or low speeds and many spots, are being dealt with, and that it is proportional to the glimpse frequency.

(To be continued.)

OPEN-HEARTH FURNACE FOR USE WITH BLASTFURNACE GAS.

THE accompanying illustrations show a design of open-hearth furnace adapted for use with blastfurnace or similar low-grade gas, the invention of Messrs. Poetter, G.m.b.H., 56, Graf Adolf Strasse, Düsseldorf. In a furnace of this kind, adapted for the heating of ingots, it is desirable that there should be produced a horizontal flame constant in direction, and of a length approximately corresponding to that of the furnace hearth. The regenerative arrangements heretofore proposed for use in open-hearth furnaces have, however, been such that the flame has been produced alternately at one or at the other end of the furnace instead of being constant in direction. In the furnace illustrated the waste gases or combustion products are passed successively or in series through a recuperator (that is to say, a heat-exchanging device not provided with a reversing valve) and through one or other of the chambers of a regenerator (that is to say, a heat-exchanging device provided with a reversing valve), whilst the fuel gas and the combustion air are passed in parallel through these heat-exchanging devices, the recuperator being preferably employed for heating the air and the regenerator for heating the fuel gas.

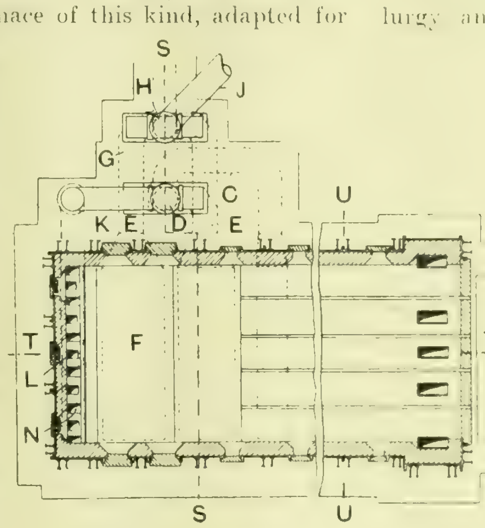


FIG. 1.

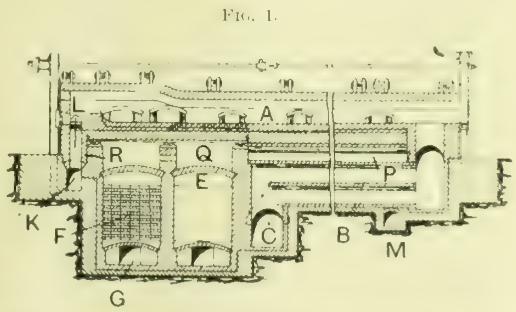


FIG. 3.

OPEN-HEARTH FURNACE FOR USE WITH BLASTFURNACE GAS.

Referring to the illustrations, Fig. 1 is a plan of the furnace, Fig. 2 is a section on the line S of Fig. 1, Fig 3 is a section on the line T of Fig. 1, and Fig. 4 is a section on the line U of Fig. 1. The waste gases from the working space A of the furnace pass, as usual, into the recuperator B arranged beneath it, and are then led through a conduit C to the reversing valve D. The undue cooling of the waste gases in the recuperator can be prevented by making it comparatively short, whilst by arranging it in front of the reversing valves the burning of these valves can be prevented. By means of the reversing valve D the waste gases are caused to pass through one or other of the passages E into one or other of the regenerative chambers F. The waste gases enter these chambers at the top, pass through them, reach the second reversing valve H through passages G arranged at the bottom of each chamber and finally arrive at the chimney. The cold gas, usually blastfurnace gas, enters through a pipe J, and then flows through the passage G to one or other of the regenerative chambers F, according to the position of the reversing valve H. After passing through this chamber the gas passes to the reversing valve D, and thence through the passage K to a passage communicating with the gas ports L. The fresh air enters the recuperator through the passage M communicating through a conduit not shown, with the arched spaces P Q beneath the level of the hearth. Passing beneath the hearth the air, which has thus been heated, reaches the air ports N through apertures not shown, in the wall R.

Iron and Steel Institute.—The annual meeting of this Institute was held at the Institution of Mechanical Engineers, Westminster, on Monday and Tuesday of last week, Mr Arthur Cooper presiding. The report of the Council set forth that during the year 108 new members were elected, and the total membership of the Institute on December 31st last was 2,119. The accounts showed that the total receipts for the year amounted to £6,483, and the expenditure to £5,793, the excess of income over expenditure being £690. On the motion of the Chairman, seconded by Sir Robert Hadfield, the report and accounts were adopted. The Bessemer gold medal was presented to Mr. Adolphe Greiner, general director of the Societie Cockerill, Seraing, a vice-president of the Institution, in recognition of his services to scientific metallurgy and his valuable contributions to the theory and

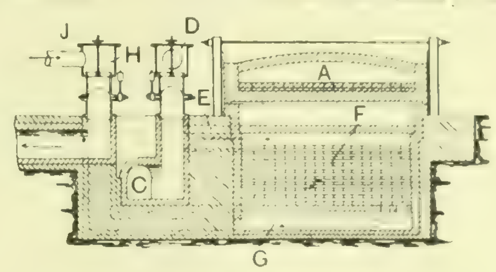


FIG. 2

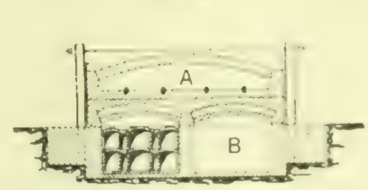


FIG. 4

practice of gas engines. A number of interesting papers were read and discussed, several of which are reproduced on other pages of this issue. The remaining ones we intend reproducing in full or in abstract in subsequent issues. On the Monday evening the annual dinner of the Institute was held at the Hotel Cecil.

Birmingham Institute of Metals.—At a meeting of the Birmingham Section of the Institute of Metals, Dr. A. G. C. Gwyer read a paper on "The Conduction of Electricity in Metals," in the course of which he said that the electrical conductivity of pure metals was always very much higher than that of mixed metals or alloys. The conductivity of the former, however, varied, for when temperature rose conductivity fell or its resistance increased. It was probable that at low temperature pure metals would become perfect conductors. That was not true of alloys.

SURFACE COMBUSTION.*

BY PROF. WILLIAM A. BONE, D.SC., PH.D., F.R.S.

The Scientific Aspects of Surface Combustion. — It is to the genius of Sir Humphrey Davy that we owe (in 1817) the original discovery of the influence of hot metallic surfaces in promoting combustion. In his classical experiments upon the ignition of gases, he had found—what is now a matter of common knowledge—that the constituents of a combustible mixture will combine, slowly, below the actual ignition temperature. This led him to enquire whether, seeing that the temperatures of flames exceed those at which solids become incandescent, a metallic wire can be maintained at incandescence by the slow combination of two gases, without actual flame. He therefore tried the effect of introducing a warm platinum wire into a jar containing a mixture of coal-gas and air, rendered non-explosive by an excess of the combustible constituents; the wire immediately became red hot, and remained so until nearly the whole of the oxygen had disappeared. In subsequent experiments, Davy proved that hydrogen is far more susceptible to such surface combustion than either ethylene or carbon-monoxide; also, that the power of inducing the phenomenon is by no means confined to metals of the platinum group—which, however, exhibit it in an eminent degree.

In 1823 the subject was investigated systematically by Dulong and Thenard, and independently also by Döbereiner, who proved that all solids, when sufficiently heated, possess the power of accelerating the slow combustion of gases below their ignition points, in varying degrees according to their chemical character and fineness of division. It was found that platinum sponge will bring about the combination of hydrogen and

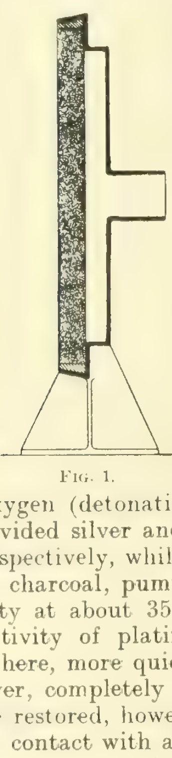


FIG. 1.

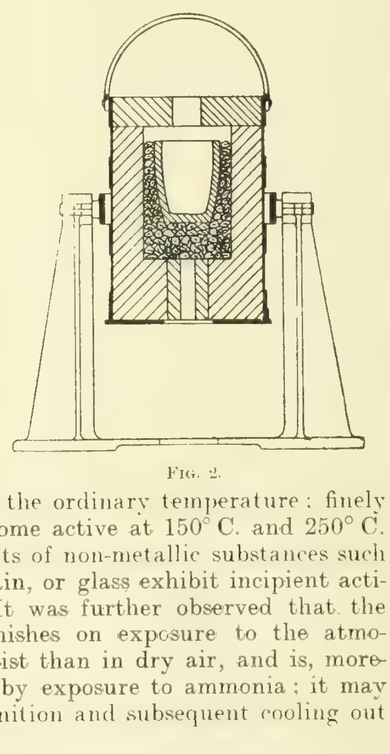


FIG. 2.

oxygen (detonating gas) at the ordinary temperature; finely divided silver and gold become active at 150° C. and 250° C. respectively, whilst fragments of non-metallic substances such as charcoal, pumice, porcelain, or glass exhibit incipient activity at about 350° C.† It was further observed that the activity of platinum diminishes on exposure to the atmosphere, more quickly in moist than in dry air, and is, moreover, completely destroyed by exposure to ammonia; it may be restored, however, by ignition and subsequent cooling out of contact with air.

In 1825, William Henry observed that when a platinum ball is immersed in a mixture of equal volumes of detonating gas ($2\ H_2 + O_2$) and ethylene, the hydrogen alone was burnt; this important observation was confirmed by Graham in 1829. Various explanations of the phenomenon were put forward by these early investigators. Davy himself suggested an electro-chemical one: "Supposing," he wrote, "oxygen and hydrogen to be in the relation of negative and positive, it is necessary to effect their combination that their electricities should be brought into equilibrium or discharged. This is done by the electrical spark or flame, which offers a conducting medium for this purpose, or by raising them to a temperature in which they become themselves conductors. Now platinum, palladium, and iridium are bodies very slightly positive with respect to oxygen. . . . They offer to the gases the conducting medium necessary for carrying off and bringing into equilibrium their electricities without any intervening energy, and accumulate the heat produced by this equilibrium."

Döbereiner, who discovered that freshly-prepared platinum black absorbs oxygen from the air, and that in this "oxygenated" condition it will cause steam to be formed when plunged into a jar of hydrogen, contended that the metal merely acts as a carrier of oxygen. On the other hand, Fusinieri (1825) maintained that it is the combustible gas (hydrogen) only which is affected by the surface, being condensed and rendered extraordinarily active by association with the surface.

The matter formed the subject of a celebrated controversy between Faraday and De la Rive in 1834-35. De la Rive strongly upheld the view that surface combustion essentially consists of a series of rapidly alternating oxidations and reductions of the catalysing material. Faraday, whilst not denying that finely-divided platinum absorbs oxygen, argued with great force that true surface combustion involves an action quite distinct from that of an oxidised wire or foil upon a combustible gas. The function of the solid is, he contended, to condense both the oxygen and the combustible gas at the surface, thus producing a condition in the surface layer comparable with that of high pressure.

It is important to observe here that, with the exception of Davy's original experiment on the glowing of a platinum wire in a non-explosive mixture of coal-gas and air, none of these early investigators appear to have experimented with incandescent surfaces, nor—with the exception of the celebrated Döbereiner lamp—was there any technical outcome of their efforts. In 1836 interest in the subject waned, and was not revived for upwards of 50 years.

A notable demonstration of the possibility of realising a flameless incandescent surface combustion in contact with metals other than those of the platinum group was given by Thomas Fletcher in a lecture at the Manchester Technical School as far back as 1887. He injected a mixture of gas and air on to a large ball of iron wire—flame being used at first in order to heat the wire to the temperature necessary to induce a continuous surface combustion; on extinguishing the flame, by momentarily stopping the gaseous mixture, the combustion continued without any flame, but with an enormous increase of temperature. Fletcher recognised that "This invisible flameless combustion is only possible under certain conditions: and one essential point is that the combustible mixture shall come into absolute contact with a substance at a high temperature. . . ." And further that "in the absence of a solid substance at a high temperature, it is impossible to cause combustion without flame," but, so far as I am aware, he did not follow up the matter beyond this point, either in its theoretical aspects or practical applications, and his work had but little influence upon contemporary opinion or practice. This perhaps was hardly to be wondered at in an age dominated by the genius of Frederick Siemens, whose favourite dictum it was that hot surfaces, by promoting dissociation, must necessarily hinder combustion; a doctrine which, I venture to think, would find no credence amongst chemists to-day. For if an incandescent surface accelerates the dissociation of steam, it must, according to a principle first enunciated by Ostwald, of necessity accelerate the combination of hydrogen and oxygen in like degree, provided the catalyst remains itself unaltered.

It is now generally recognised by chemists as a well-established principle that all hot surfaces have an accelerating influence upon chemical changes in gaseous systems; or, in other words, that if at any temperature a gaseous system "A" tends to pass over into another system "B," contact with a solid at the same temperature will accelerate the process. To take a very simple example, if a mixture of hydrogen and oxygen in their combining proportions (electrolytic gas) be maintained in an enclosure with smooth glass walls at a temperature of (say) 450° C., there would certainly be a tendency to form steam, but the rate of change would be negligibly small. If, however, there be brought into the system some porous solid material at the same temperature, so that a large

* Abstract of lecture delivered before the North-east Coast Institution of Engineers and Shipbuilders, February 21st, 1913.

† The temperatures given in the introductory portion of the lecture are in degrees Centigrade.

surface is exposed to the gases, the rate of change would at once be rapidly accelerated in the layer of gas immediately in contact with the hot surface. Steam, the product, would diffuse outwards from the surface, and the supplies of hydrogen and oxygen at the surface would be renewed by diffusion inwards. Thus combustion would proceed heterogeneously at the surface until the transformation of the original electrolytic gas into steam was complete. In the circumstances just cited, the rate of combustion, although now quite measurable, would probably be insufficient to cause any self-heating of the enclosure. The temperature would remain at 450° C., which is well below either the ignition temperature of the combustible mixture or the point at which a solid would attain even incipient incandescence.

It is therefore necessary to distinguish between two possible conditions under which gaseous combustion may occur, viz.: (1) *Homogeneously*—that is to say, equally throughout the system as a whole, at temperatures below the ignition points slowly and without flame, and at temperatures above the ignition point—rapidly and with flame; and (2) *Heterogeneously*, or only in layers immediately in contact with a hot or incandescent surface ("surface combustion"). It is also necessary to remember that, *ceteris paribus*, the heterogeneous surface combustion is a faster process than the normal homogeneous combustion of ordinary flames.

My own investigations upon surface combustion began in 1902 with a systematic attempt to elucidate the factors operative in the slow combination of hydrogen and of carbon monoxide in contact with various hot surfaces (*e.g.*, porcelain, fire-clay, magnesia, platinum, gold, silver, copper and nickel oxides, &c.) at temperatures below 500°. Into the details of these earlier experiments, which preceded and led up to the technical developments about which I shall speak later, I do not propose to enter; it will be sufficient for my present purpose if I say that it was proved beyond all question (1) that the power of accelerating gaseous combustion is possessed by all surfaces at temperatures below the ignition point in varying degrees, dependent upon their chemical characters and physical texture; (2) that such an accelerated surface combustion is dependent upon an absorption or condensation of the combustible gas and, possibly also, of the oxygen, by the surface, whereby it becomes activated (probably ionised, as the physicists would call it) by association with the surface; and (3) that the surface itself becomes electrically charged during the process. Finally, certain important differences between homogeneous combustion in ordinary flames and heterogeneous combustion in contact with a hot surface from a chemical point of view were established, so that there can be no longer any doubt as to the potency and reality of the phenomenon.

My next contention is that if hot surfaces possess the power of accelerating gaseous combustion at temperatures below, or in the neighbourhood of, the ignition point, the same power must also be manifested in even a greater degree at higher temperatures and especially so when the surface itself becomes incandescent. Indeed, there are experimental grounds for the belief that not only does the accelerating influence of the surface rapidly increase with the temperature, but also that the differences between the catalysing powers of various surfaces, which at low temperatures are often considerable, diminish with ascending temperatures until at bright incandescence they practically disappear.

Assuming, for the moment, the validity of this conclusion, it may be profitable for us to consider how far it is possible to accelerate the process of combustion in an ordinary flame. We are apt to think of ordinary flame combustion as an instantaneous process, whereas when considered in terms "molecular time," it is a very slow transaction. Thus, for example, when electrolytic gas is ignited by a spark near the closed end of a tube, the flame is initially propagated by conduction with a uniform slow velocity of 20 metres per second. During this preliminary period of inflammation, the total duration of chemical change in each successive layer of gas is something like the order of one-fiftieth part of a second, an interval at least one hundred million times as long as the average interval between successive molecular collisions in electrolytic gas at the ordinary temperature.

After the flame has travelled a short distance along the tube it is rapidly accelerated, under the influence of compression waves reflected from the closed end of the tube, until a new condition known as detonation is set up. In detonation the flame is propagated through the mixture by adiabatic compression at an enormously great and constant velocity, amounting in the case of electrolytic gas at atmospheric pressure to no less than 2,820 metres per second. The combustion now proceeds under conditions of maximum intensity, both as regards the actual duration of chemical change and the temperatures produced in each layer of the burning gases. Some years ago, in conjunction with Dr. Bevan Lean, I found that the duration of chemical action in each successive layer of electrolytic gas in which detonation has been determined, does not exceed one five thousandth or possibly one ten thousandth part of a second, *i.e.*, an interval less than [illegible] of the corresponding duration in an ordinary flame (inflammation) with the same mixture.

Such consideration as I have thus briefly explained convinced me some years ago that if an explosive gaseous mixture be either injected on to or forced through the interstices of a porous refractory incandescent solid under certain conditions, which will be hereafter explained, a greatly accelerated combustion would take place within the interstices or pores, or, in other words, within the boundary layers between the

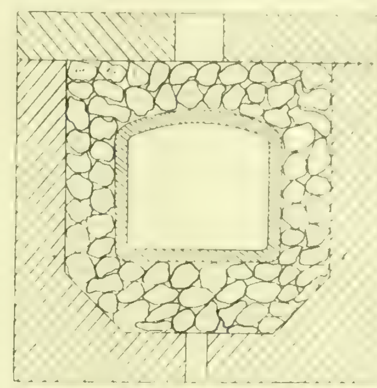


FIG. 3.

gaseous and solid phases wherever these may be in contact and the heat developed by this intensified combustion would maintain the surface in a state of incandescence without any development of flame, thus realising the conception of flameless incandescent surface combustion, as a means of greatly increasing the general efficiency of heating operations wherever it can be conveniently applied.

There are two further points which I particularly wish to make clear to you. In dealing with gaseous interactions at high temperatures it is necessary to think in terms of what I may call molecular dimensions. Our ordinary units of time, space, and mass are altogether too gross, and must be discarded if we would wish to form a true mental picture of the mechanism of combustion; when, therefore, I speak of combustion as occurring "within the interstices or pores" of an incandescent solid, it must be understood that I mean porosity in a molecular sense. A solid may appear to the eye to be dense, and yet be highly permeable to the molecules of a gas; from this point of view it is only vitreous surfaces, such as glass, which are (relatively speaking) non-porous to gases, and even glass when it becomes devitrified is sufficiently porous to induce a slow surface combustion.

In the second place I want to emphasize the fact that the incandescent solid plays a specific rôle in this surface combustion; it is no mere idle looker-on at the surging crowd of reacting molecules which swarm around it. On the contrary, it so galvanises and incites the dormant affinities between the combustible gas and oxygen, that the stately minuet of ordinary combustion gives place to the wild intoxication of the Venusberg. The manner in which the surface acts is still perhaps a matter of conjecture, but the fact that it so acts can no longer be disputed. In a discussion which took place at the British Association in 1910, Sir J. J. Thomson insisted that combustion is concerned not only with atoms and molecules, but also with electrons, *i.e.*, bodies of much smaller

dimensions and moving with very high velocities, and suggested that in reference to the influence of hot surfaces in promoting combustion it was not improbable that the emission of charged particles from the surface was a factor of primary importance. It is known that incandescent surfaces emit enormous streams of electrons travelling with high velocities, and the actions of these surfaces in promoting combustion may ultimately be found to depend on the fact that they bring about the formation of layers of electrified gas in which chemical changes proceed with extraordinarily high velocity.

The New Processes of Incandescent Surface Combustion.—Leaving the theoretical aspects of the subject, I will now describe some of the more important features of two processes of incandescent surface combustion recently evolved in Leeds under my direction, in which a homogeneous explosive mixture of gas and air, in the proper proportions for complete combustion (or with air in slight excess thereof), is caused to burn without flame in contact with a granular incandescent solid, whereby a large proportion of the potential energy of the gas is immediately converted into radiant form. The advantages claimed for the new system are: (1) The combustion is greatly accelerated by the incandescent surface, and, if so desired, may be concentrated just where the heat is required; (2) the combustion is perfect with a minimum excess of air; (3) the attainment of very high temperatures is possible without the aid of elaborate regenerative devices; and (4)

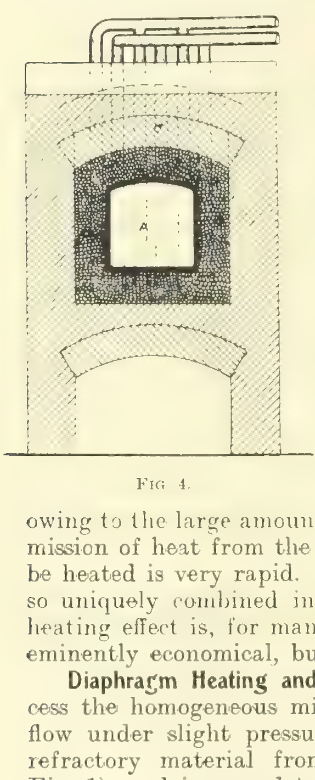


FIG. 4.

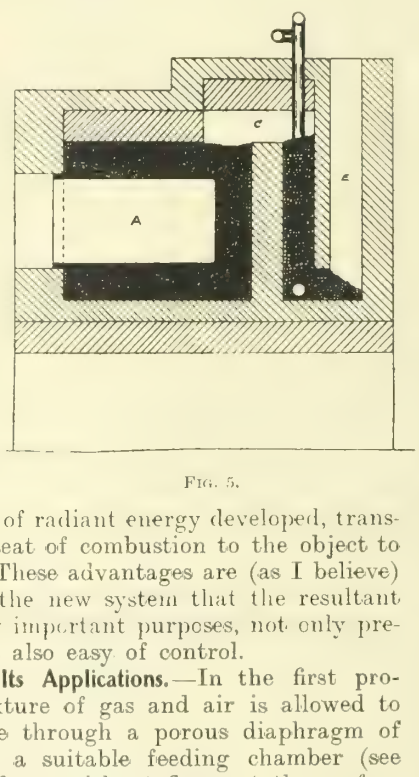


FIG. 5.

owing to the large amount of radiant energy developed, transmission of heat from the seat of combustion to the object to be heated is very rapid. These advantages are (as I believe) so uniquely combined in the new system that the resultant heating effect is, for many important purposes, not only pre-eminently economical, but also easy of control.

Diaphragm Heating and Its Applications.—In the first process the homogeneous mixture of gas and air is allowed to flow under slight pressure through a porous diaphragm of refractory material from a suitable feeding chamber (see Fig. 1), and is caused to burn without flame at the surface of exit, which is thereby maintained in a state of red-hot incandescence. The diaphragm is composed of granules of firebrick, bound together into a coherent block by suitable means; the porosity of the diaphragm is graded to suit the particular kind of gas for which it is to be used, but for undiluted coal-gas, or coal-gas containing only a small proportion of water-gas, a diaphragm so porous that the gaseous mixture will readily flow through it at a pressure of $\frac{1}{8}$in to $\frac{1}{4}$in. water gauge is employed. The diaphragm is mounted in a suitable casing, the space enclosed between the back of the casing and the diaphragm constituting a convenient feeding-chamber for the gaseous mixture which is introduced at the back. Such a mixture may be obtained in either of two ways, namely (1) by means of suitable connections through a Y-piece with separate supplies of low-pressure gas and air (2in. or 3in. W.G. is sufficient), or (2) by means of an "injector" arrangement connected with a supply of gas at a pressure of 2lbs. per square inch; the gas in this case draws in its own air from the atmosphere in sufficient quantity for complete combustion, the proportions of gas and air being easily regulated by a simple device.

To start up a diaphragm, gas is first of all turned on and ignited as it issues at the surface; air is then gradually added until a fully aerated mixture is obtained. The flame soon becomes non-luminous and diminishes in size; a moment later it retreats on to the surface of the diaphragm, which at once assumes a bluish appearance; soon, however, the granules at the surface attain an incipient red heat, producing a curious mottled effect; finally, the whole of the surface layer of granules becomes red-hot, and an accelerated "surface combustion" comes into play. All signs of flame disappear, and there remains an intensely glowing surface—a veritable wall of fire, but without flame—throwing out a genial radiant heat which can be steadily maintained for as long as required.

The manifold advantages of such a radiant diaphragm as a method of heating may be summarised as follows: Firstly, the actual combustion is confined within a very thin layer (a few millimetres only) immediately below the surface, and no heat is developed in any other part of the apparatus; secondly, the combustion of the gas, although confined within such narrow limits, is perfect, for when once the relative proportions of gas and air have been properly adjusted, no trace of unburnt gas escapes from the surface. Thirdly, the temperature at the surface of the diaphragm can be instantly varied at will by altering the rate of feeding of the gaseous mixture; there is practically no lag in the temperature response, a circumstance of great importance in operations where a fine regulation of heat is required. The temperature of a diaphragm working on a coal gas and air mixture, at a given rate of feeding, depends on whether or not the intense radiation from its surface is impeded; with a freely radiating surface the temperature of a properly-made diaphragm may be maintained at anything up to about 850° C., according to the rate of supply of the combustible mixture. Fourthly, a plane diaphragm such as this may be used in any position, *i.e.*, at any desired angle between the horizontal and vertical planes. Fifthly, the diaphragm method is amenable to a variety of combustible gases—coal or coke oven gas (either undiluted or admixed with water-gas), natural gas, petrol-air gas, carburetted water-gas, are all well suited in cases where unimpeded radiation is required. Finally, the incandescence in no way depends upon the external atmosphere. When once the diaphragm has become incandescent, and the proportions of air and gas supplied in the mixing chamber at the back have been properly adjusted, the surface will maintain its incandescence unimpaired, even in an atmosphere of carbon dioxide. Plane diaphragms of all sizes up to 4 sq. ft. in area have been constructed and successfully operated, and their durability and radiant power are unimpaired, even after long continued use.

Incandescent Surface Combustion in a Bed of Refractory Granular Material.—The second process is applicable to all kinds of gaseous or vaporised fuels; it consists essentially in injecting, through a suitable orifice at a speed greater than the velocity of back firing, an explosive mixture of gas (or vapour) and air in their combining proportions into a bed of incandescent granular refractory material which is disposed around or in proximity to the body to be heated. I can perhaps best describe the process by the aid of two diagrams showing its applications to the heating of crucible and muffle furnaces.

Fig. 2 shows the process as applied to a crucible furnace. The crucible is surrounded by a bed of refractory incandescent granular material. The mixture of gas and air is injected at a high velocity through a narrow orifice in the base of the furnace, and as it impinges upon the incandescent bed, combustion is instantaneously completed without flame. The seat of this active surface combustion is in the lowest part of the bed; the burnt gases, rising through the upper layers, rapidly impart their heat to the bed, maintaining it in a high degree of incandescence. Fig. 3 shows a similar arrangement for the heating of a muffle furnace which needs no further explanation.

It is obvious that this process is adaptable to many other furnace operations, as, for example, to the heating of retorts, annealing furnaces, and the like. Moreover, it is not essential that the bed of refractory material shall be disposed around the vessel or chamber to be heated; it may be equally well packed into tubes, or the like, traversing the substance

or medium to be heated. This latter modification is, as we shall see later, important in relation to the melting of metals or alloys which are fusible at temperatures below about 600° C. (say, 1,100° Fah.), and also in relation to steam raising to multitubular boilers. By this process much higher temperatures are attainable with a given gas than by the ordinary methods of flame combustion, without a regenerative system, and as a matter of fact we have found that with any gas of high calorific intensity (such as coal-gas, water-gas, or natural gas) the upper practicable temperature limit is determined by the refractoriness of the material composing the chamber to be heated (*i.e.*, the muffle or crucible) rather than by the possibilities of the actual combustion itself. When I tell you that in a crucible fired by coal-gas on this system we have melted Seger-cone No. 39, which, according to the latest determination of your Reichsanstahlt, melts at 1,880° C. (3,416° Fah.), and also that we can easily melt platinum, you will appreciate the possibilities of the method in regard to high temperatures with gas-fired furnaces.

Indeed, at one stage of the investigation, we had considerable difficulty in obtaining materials for the construction of muffles and crucibles which would stand the high temperatures obtainable with coal-gas, but we have now succeeded in constructing muffles which will withstand temperatures up to 1,400° or 1,500° C. (say, 2,550° to 2,730° Fah.). It will also be obvious that the bed of incandescent granular material must be composed of a substance which will not at the working temperature exercise a fluxing action upon the walls of the crucible or muffle, or walls of the furnace.

As I have already stated, the method is applicable to all kinds of gaseous and vaporous fuels, but naturally the maximum temperature obtainable in any given case will depend upon the volume and heat capacity of the products for a given heat development in the bed. Thus, whilst with coal-gas, water-gas, or natural gas, it is possible to attain temperatures of up to at least 2,000° C. (or, say, 3,630° Fah.), with a producer gas of low calorific intensity, such as Mond gas, about 1,500° C. (say, 2,730° Fah.) would probably be the maximum temperature obtainable without regeneration. With some degree of heat recuperation, which in most, if not all, cases is quite practicable, still higher temperatures can be attained. Thus, for example, a few months ago at one experimental station, which was then located in Leeds, we successfully fired a large regenerative furnace for the heating of a muffle measuring 8ft. by 3ft. by 3ft. (internal dimensions), in which the air supply was pre-heated to a temperature of up to 300° C. wholly at the expense of the waste gases, as shown diagrammatically in Figs. 4 and 5. The mixture of gas and pre-heated air was fed in at the front end of the furnace, and caused to burn flamelessly in contact with incandescent granular material surrounding the muffle chamber; the hot products of combustion were afterwards led downwards through a second granular bed disposed round a system of iron pipes through which the air supply was fed; we were thus able to maintain the muffle at 1,000° C. (say, 1,830° Fah.), whilst the waste gases left the system at less than 200° C. (say, 400° Fah.) only.

Not only is it possible to obtain, with a given gas consumption, a much higher temperature by the employment of "surface combustion" than with ordinary "flame" heating, but also it naturally follows that a given temperature can be maintained with a considerably reduced fuel consumption. A large number of tests made at one experimental station with small and medium-sized muffle furnaces have shown that in order to maintain a temperature of, say, 1,000° C. (say, 1,830° Fah.), ordinary flame-heated furnaces require between $1\frac{3}{4}$ and $2\frac{1}{2}$ times the amount of gas used in a "surface combustion" furnace of similar dimensions; moreover, independent trials carried out in New York, in which our furnaces were pitted against the best American types, proved that in order to maintain a temperature of 1,400° C. (2,550° Fah.) we practically halved their gas consumption, whilst to maintain 800° C. (1,470° Fah.) our consumption was about 0·7 of theirs. With the addition, in the case of our furnaces, of a simple regenerative system, the already big margin in our favour is considerably increased.

(To be continued.)

THE CORRODIBILITY OF NICKEL, CHROMIUM, AND NICKEL-CHROMIUM STEELS.*

BY J. NEWTON FRIEND, WALTER WEST, AND J. LLOYD BENTLEY

IN a previous communication to this Institute,† the authors gave in detail the results of several series of experiments carried out with the object of determining the influence of nickel and chromium, both separately and together upon the corrodibility of the steel with which they are alloyed. As those experiments were not continued for periods of longer than about two months, the accompanying research was undertaken with a view to determining the result of exposing samples of the same steels to corrosive influences for a twelvemonth. Owing to the removal of one of the authors from Darlington, however, the work had to be stopped after six months, but the results are sufficiently interesting and important to bear publication.

The steels experimented upon were kindly supplied in the form of bars by Messrs. Cammell, Laird, & Co., of Sheffield, and after being tool-turned were sliced into discs 0·7 centimetre thick and 2·8 centimetres in diameter by the Darlington Forge Company. To both of these firms the authors wish to express their hearty thanks. The complete analyses of the steels, kindly supplied by Mr. B. Deby, of Sheffield, are given in the paper above quoted. Although the steels have not a perfectly uniform composition with respect to the alloying elements other than nickel and chromium, the discrepancies are relatively small and of minor importance compared with the range of nickel and chromium covered. Any results obtained with these, therefore, may probably be regarded as reliable, if the steels are of uniform composition and free from segregation. The steel discs were carefully polished with emery paper, weighed, and subjected to corroding influences. At the conclusion of the experiments the discs were removed, scraped, and washed. After drying they were weighed a second time, and the loss in weight taken as a measure of the corrosion.

Tap-water Tests.—The steel discs were laid flatwise on circular sheets of paraffin wax in glass beakers of 500 cubic centimetres of water. The beakers were kept in a dark cupboard to prevent any irregularity of corrosion consequent upon unequal illumination. The paraffin served to reduce the possibility of galvanic action to a minimum, and also to prevent the corrosive action of silica always observed if iron lies for any length of time in direct contact with glass. After six months the discs were removed, cleaned, and weighed, with the results given in Table I.

TABLE I.—*Corrosion of Steels in Tap Water (Six Months' Exposure).*

Steel. No.	Nickel. Per cent.	Chromium. Per cent.	Original Weight. Grammes.	Loss in Weight. Grammes.	Corrosion Factor. Six months.	Corrosion Factor. Two months.
1	—	—	33·5514	0·3114	100	100
2	—	—	38·9199	0·3259	104	108
3	3·72	—	28·9544	0·0784	23	83
4	6·14	—	30·2589	0·3339	107	69
5	26·24	—	32·8654	0·3344	108	51
6	—	1·12	28·7019	0·2269	73	85
7	—	3·58	28·2184	0·1909	61	58
8	—	5·30	30·5669	0·1849	59	43
9	3·4	1·00	31·4019	0·3159	101	77
10	3·5	1·12	30·4404	0·3384	109	87

In the last column but one, the corrosion of the first steel is taken as 100, and that of every other steel is expressed proportionately. The figures in the last column represent the corrosion factors of the steels as determined in a similar manner a year ago, after two months' exposure, as detailed in the paper already referred to.

Sea-water Tests.—These experiments were carried out in a precisely similar manner to the preceding ones, save that the

* Paper presented at the annual meeting of the Iron and Steel Institute, May 1st, 1913.

† See the "Mechanical Engineer," May 17th, 1912, page 621, Vol XXIX.

liquid corrosive medium was sea water from Bridlington Bay. The results are given in Table II.

TABLE II.—*Corrosion of Steels in Sea Water (Six Months' Exposure).*

Steel No.	Nickel. Per cent.	Chromium. Per cent.	Original Weight. Grammes.	Loss in Weight. Grammes.	Corrosion Factor. Six months.	Corrosion Factor. Two months.
1			37·8739	0·2689	100	100
2		—	38·1264	0·2974	111	105
3	3·72		31·2919	0·2909	108	77
4	6·14		29·3179	0·2169	80	79
5	26·24	—	29·0697	0·1087	40	45
6	—	1·12	30·0309	0·0809	30	60
7		3·58	29·4212	0·2292	85	26
8	—	5·30	30·3412	0·1192	44	23
9	3·4	1·00	31·3254	0·2874	107	82
10	3·5	1·12	30·5959	0·2269	84	90

In the last column, as before, are given the corrosion factors of the steels as determined in the previous investigation under similar conditions after an exposure of two months only. The two sets of results are reasonably concordant, and exhibit the superiority of high nickel and of chromium steels over ordinary carbon steels in their resistance to the corrosive action of sea water.

Sulphuric Acid Tests (0·05 per cent.)—The results given in Table III. were obtained in an exactly similar manner to the preceding, the corroding liquid being 0·05 per cent. sulphuric acid, that is, 0·5 gramme of acid in 1,000 grammes of solution with water.

TABLE III.—*Corrosion of Steels in 0·05 per cent. Sulphuric Acid (Six Months' Exposure).*

Steel. No.	Nickel. Per cent.	Chromium. Per cent.	Original Weight. Grammes.	Loss in Weight. Grammes.	Corrosion Factor. Six months.	Corrosion Factor. Two months.
1	—	—	38·8011	0·4971	100	100
2	—	—	34·4779	0·5139	103	98
3	3·72	—	31·6814	0·3054	61	85
4	6·14	—	29·9814	0·4774	96	82
5	26·24	—	35·4589	0·5569	112	54
6	—	1·12	28·9284	0·4444	89	71
7	—	3·58	29·2919	0·5069	102	68
8	—	5·30	30·3689	0·3513	80	68
9	3·4	1·00	31·3859	0·5089	102	87
10	3·5	1·12	30·4184	0·4644	93	93

Alternate Wet and Dry Tests.—These experiments were carried out in a precisely similar manner to those detailed in the previous paper. The steel discs were laid on a perforated paraffin sheet in a thermostat some 30 centimetres in diameter, and water was allowed to slowly drip into the latter. When the vessel became full, the water was automatically syphoned off. The discs were thus alternatively wet and dry, the process of filling the thermostat requiring four hours each time. A loosely fitting cover was placed at the top to keep out dust and to maintain darkness within, in order to prevent any irregularity of corrosion consequent upon unequal illumination. Precisely the same discs of steel were used in these experiments as before, so that if the power of resistance to long and short exposure is the same, the results may reasonably be expected to closely resemble one another, since discrepancies due to unavoidable variation in the composition of different parts of the same steel bar from which the discs were sliced cannot occur. As will be seen from Table IV. such was indeed the case.

TABLE IV.—*Corrosion of Steels Exposed to Alternate Wet and Dry (Six Months' Exposure).*

Steel No.	Nickel. Per cent.	Chromium. Per cent.	Original Weight. Grammes.	Loss in Weight. Grammes.	Corrosion Factor. Six months.	Corrosion Factor. Two months.
1	—	—	32·2830	0·4120	100	100
2		—	38·4450	0·4590	111	100
3	3·72	—	28·2705	0·2505	61	43
4	6·14	—	31·7675	0·1815	44	36
5	26·24	—	30·7840	0·0410	10	8
6		1·12	28·3334	0·4504	109	93
7		3·58	28·3080	0·1060	25	30
8		5·30	30·7850	0·0790	19	21
9	3·4	1·00	29·7471	0·2474	60	47
10	3·5	1·12	32·6552	0·2792	68	52

Alternate Heating and Cooling.—These experiments, the results of which are given in Table V., consisted in placing the steel discs on sheets of glass in a perforated tray on a large thermostat, 30 centimetres in diameter. The vessel was filled with water, and maintained at 86° C. during the day time, but allowed to cool at night. The corrosion was fairly rapid, and after 35 days the discs were removed.

TABLE V.—*Corrosion of Steels Exposed to Alternate Heating and Cooling for 35 Days.*

Steel. No.	Nickel. Per cent.	Chromium. Per cent.	Original Weight. Grammes.	Loss in Weight. Grammes.	Corrosion Factor.
1	—	—	35·3970	0·1520	100
2	—	—	36·8470	0·1500	100
3	3·72	—	34·5280	0·1790	117
4	6·14	—	27·4480	0·1520	100
5	26·24	—	26·0510	0·0950	64
6	—	1·12	29·4780	0·0780	51
7	—	3·58	29·9920	0·1820	120
8	—	5·30	32·3720	0·0800	53
9	3·4	1·00	28·5600	0·1760	116
10	3·5	1·12	27·8800	0·2090	137

Discussions of the Results.—For the sake of facilitating the discussion of these results, Table VI. has been drawn up, in which the corrosion factors of the steels as obtained in the present research and the previous one are recorded. Corroding media may be divided into two groups, namely, acid and neutral, and the results obtained are usually very different in

TABLE VI.

Steel. No.	Nickel. Per cent.	Chromium. Per cent.	Corrosion Factor in Tap Water. 6 months.	Tap Water. 2 months.	Sea Water. 6 months.	Sea Water. 2 months.	Wet and Dry. 6 months.	Wet and Dry. 2 months.	0·05 per cent. Acid. 6 months.	0·05 per cent. Acid. 2 months.	Hot Water. 35 days.	Mean Result.	Corrosion Factor in 0·5 per cent. Acid. 2 months.
1	—	—	100	100	100	100	100	100	100	100	100	100	100
2	—	—	104	108	111	105	111	100	103	98	100	104	259
3	3·72	—	23	83	108	77	61	43	61	85	117	73	55
4	6·14	—	107	69	80	79	44	36	96	82	100	77	63
5	26·24	—	108	51	40	45	10	8	112	54	64	55	8
6	—	1·12	73	85	30	60	109	93	89	71	51	73	223
7	—	3·58	61	58	85	26	25	30	102	68	120	64	61
8	—	5·30	59	43	44	23	19	21	80	68	53	46	78
9	3·4	1·00	101	77	107	82	60	47	102	87	116	84	132
10	3·5	1·12	109	87	84	90	68	52	93	93	137	90	413

the two cases. Very dilute acid, such as 0·05 per cent. sulphuric acid, resembles the neutral corroding media in its action, and this we might reasonably expect, since the so-called neutral media (tap water, sea water, &c.) usually contain a small quantity of acids, such as carbonic. For this reason the results obtained with such relatively strong acid as 0·5 per cent. sulphuric acid in last year's research are placed in a separate column, all the others being grouped together as bearing legitimate comparison.

The following observations are worthy of note: (1) The two carbon steels exhibit a remarkably equal resistance towards corrosion in all the neutral and faintly acid media. In the stronger acid (0·5 per cent. sulphuric acid) steel No. 2 was badly attacked, as were also steels 6 and 10. (2) In the case of the nickel steels the results obtained after six months' exposure are somewhat less regular than those after merely two months' treatment. This is particularly so with the tap-water experiments. The results appear to indicate that in long exposure tests the influence of the alloyed nickel (steels Nos. 4 and 5) is not as beneficial as shorter tests would suggest. The experiments with the chromium steels appear to agree very well with previous results. These results apparently accord with those of practical men who have not infrequently observed that whilst nickel steels in practical use will for a time withstand corrosion to a remarkable degree, they are apt, after very prolonged exposure, to "perish" very rapidly. This is possibly traceable to the gradual breaking down of complexes highly resistant to corrosion into two or more bodies capable of setting up galvanic activity and accelerating corrosion. On the other hand, it is well known that special steels such as these are particularly liable to segregation, and wherever segregation occurs differences of potential exist, leading in favourable circumstances to rapid corrosion. Thus segregation may easily more than counterbalance the otherwise preservative action of the alloying metal. For this reason too much stress must not be laid on individual experiments, and the mean results (given in the last column but one) of the nine sets of experiments in neutral or faintly acid corroding media may be regarded as most trustworthy.

As a considerable amount of research has been carried out by different investigators upon the influence of alloyed nickel and chromium on the corrodibility of steel, it is instructive to collect the available material together and to learn what conclusions may be reasonably drawn from it. In Table VII. is given a list of the more important published researches, the result being, from want of a better standard, expressed relatively to the corrodibilities of the carbon steels (always taken as 100) free from nickel or chromium, as used by the different investigators. They are, of course, only approximately comparable, for the various carbon steels used as standards, not being identical, could obviously not be expected to corrode at exactly the same rate. The error, however, will not be very great, inasmuch as good steels of average composition usually corrode at approximately the same rates, as has been shown by the extensive researches of Parker, Rudeloff, Howe and Stoughton, and others. In the last column of the table, results obtained with nitric acid are omitted, as they are not comparable with those obtained with hydrochloric and sulphuric acids, in consequence of the well known but ill understood passivifying action of the nitric acid, which produces disturbing effects. Further, several otherwise useful researches have had to be excluded from this list, owing to lack of sufficient published experimental details to render comparison possible.

TABLE VII.

No.	Authority.	Nickel per Cent.	Chromium per Cent.	Commission Factor in Neutral or very faintly Acid Media.	Commission Factor in Decidedly Acid Media (save Nitric Acid).	Remarks.
		—		100	100	—
1	Crowe[1]	2·9-2·6	—	98		
2	Howe[2]	3·03	-	77	-	
3	Wiggin[3]	3·03	- -	64	-	
4	Friend, Bentley, and West ..	3·72	-	73	55	—
5	Riley[4]	5·00	·	—	83	—
6	Diegel[5]	6·14	- -	65*		*Seawater only.
7	F., B., & W. ..	6·14	-	77	63	—
8	Riley	25·00	—	--	1·15	—
9	Howe..........	26·00	—	31	—	-
10	F., B., & W. ..	26·24	- -	55	8	- -
11	Diegel	29·7	—	26*		*Seawater only.
12	F., B., & W. ..	—	1·12	73	223*	*0·5 per cent. sulphuric acid.
13	Hadfield[6]	- -	1·18	-	44*	*50 per cent. sulphuric acid.
14	F., B., & W. ..	--	3·58	64	61	—
15	Hadfield	—	5·19	—	64	—
16	F., B., & W. ..	-	5·30	46	78	
17	Hadfield		9·18		75	-
18	F., B., & W. ..	3·4	1·00	84	132	—
19	F., B., & W. ..	3·5	1·12	90	413	

[1] Crowe, *Proceedings of the Cleveland Institution of Engineers*, March 1st, 1909.
[2] Howe, J., *Journal of the Iron and Steel Institute*, 1900, No. II., p. 567.
[3] Wiggin, *ibid.*, 1895, No. II., p. 164. The open-hearth steel used by Wiggin is taken as the standard in preference to the Bessemer steel also used by him, since the carbon and phosphorus content of the open-hearth steel more closely approximates to that of the nickel steel used.
[4] Riley, *ibid.*, 1889, No. I., p. 45. The data given by Riley are very sparse, and greatly reduce the value of the work.
[5] Diegel, *Verhandlungen des Vereins zur Beförderung des Gewerbfleisses*, 1903, Bd. v., p. 157.
[6] Hadfield, R. A., *Journal of the Iron and Steel Institute*, 1892, No. II., p. 92.

It will be observed that the results in Table VII. show a very remarkable agreement, particularly when it is remembered under what diverse conditions they have been obtained. In neutral and acid corroding media alike, the presence of alloying nickel exerts a markedly protecting action, which increases with the percentage of the nickel. In order to have any appreciable influence, however, the percentage of nickel should not fall below 3. Eaton, of the U.S. Navy, states that the results of three sets of experiments carried out in America show that from 0 to 2 per cent. of nickel exerts no protective action, but 3 to 4 per cent. reduces the corrosion factor to 95. These numbers are not included in the table, as Eaton merely quoted from memory.

The chromium steels behave differently. In neutral solutions they corrode less rapidly than mere carbon steels, but their behaviour towards acid is very eccentric. The 1·12 chromium steel (No. 12) was very severely attacked by the 0·5 per cent. sulphuric acid, and unless this is attributable to segregation in the particular disc employed, it would appear that a little chromium favours the solution of steel in acid. This would agree with the observations of Stodart and Faraday and Gruner, and it is also interesting, in connection with the observation of Monnartz, that the presence of alloyed chromium increases the solubility of iron in nitric acid, the maximum solubility being observed with 4 per cent. chromium. Above this percentage, the solubility falls off, until with 20 per cent. of chromium the alloy is practically insoluble in nitric acid. Although Hadfield's experiments were carried out with much stronger sulphuric acid than ours, the agreement of steels Nos. 14 to 17 is very remarkable, apparently indicating the existence of an optimum chromium content which yields the maximum resistance to acid attack, and that if this amount be either not reached, or else exceeded, a more corrodible alloy is the result. From the above it is evident that the results obtained in acid corroding media give relatively no clue to the corrodibility of the metal under ordinary conditions of exposure. This again emphasizes the fact that acceleration tests as usually carried out with acids yield very misleading results—an observation in perfect harmony with the results of Frazer, C. M. Chapman, and of the British Association Corrosion Committee.

From the results from steels Nos. 18 and 19, it is evident that the corrosion factor is not an additive quantity. Thus, for example, the 3·72 per cent. nickel steel and 1·12 per cent. chromium steel (Nos. 4 and 12) yield the same corrosion factor, the protection being in each case $100 - 73 = 27$ per cent. It might therefore be expected that by having these together in one steel, as in steel No. 19, the same corrosion factor would be obtained as by doubling the nickel or the chromium content alone. Such is not the case, however. On the contrary, both steels 18 and 19 are more corrodible than steels 4 and 12, as though the chromium and the nickel sought to neutralise each other's action.

In conclusion, the authors would again emphasize the importance of carefully studying the influence of alloying elements upon the corrodibility of steel, for it is only in this way that any hope can be entertained of solving the numerous problems connected with the corrosion of iron and steel.

EXPLOSION OF A TURBO-DYNAMO.

WE are indebted to "The Electrical Review" for the following particulars relating to a serious mishap of a nature fortunately rare in these days of powerful generators, which occurred on March 8th last in the Essen power station of the Rheinisch Westfalischen Company. Shortly after 11 p.m., the No. 4 turbine—a Zoelly machine running at 1,000 revs. per minute and coupled to a 5,000 kw., 5,250-volt alternator with salient rotor poles—began to emit peculiar rising and falling sounds; meanwhile the output of the machine fluctuated widely. The set was at once unloaded, the main switch being opened when the output was reduced to 900 kw. The alternator then showed normal voltage, but, while the main stop valve was being closed, the whole machine "burst." Wreckage flew in all directions and wrought considerable havoc. One piece of the stator, weighing several tons, was thrown through the wall of the power house, and, having damaged the tramway track, ricochetted against and damaged a building on the opposite side of the street. Five of the poles, weighing about 2,000lbs., were hurled through the roof, while the remaining seven were found in various parts of the power house. One pole soared over the houses on the other side of the street and buried itself deeply in the ground, while two others were found well over 100 yards away near the coke ovens of the Victoria Mathias pit. The engine room was strewn with splinters of iron and wood after the disaster, but with the exception of an adjacent 5,000 kw. set which was set on fire, no serious damage was done to the remaining valuable plant in the building. The power house building and some of the adjacent property belonging to the company were, however, badly damaged, but fortunately no loss of life or injury to person was involved. The cause of the disaster has not been determined, and it is not believed that any definite conclusion can be reached in this respect. The town fire brigade and the station staff, aided by employés from the neighbouring colliery, soon restored comparative order to the works, and it is worth recording that current supply was only interrupted for about five minutes.

CORRESPONDENCE.

Report of Royal Commission on University Education.

To the Editor of "The Mechanical Engineer."

Sir,—One would have thought that engineering was a sufficiently important subject to have a faculty all to itself, for even music has a separate faculty. At present engineering is a sort of excrescence of science. The Commissioners propose that it should be mixed up with something else, and the compound called "Technology," so that if this should ever come to pass, some of our distinguished engineers will be able to state that they have the D.T.'s (*i.e.*, that they each possess the degree of Doctor of Technology) ! ! ! "which," as Euclid would have said, "is absurd," and being absurd, it cannot be. Therefore let us have a separate faculty for the important subject of engineering, and let the degrees be B.E. and D.E. (Bachelor and Doctor of Engineering), which would be understood by the man in the street.—Yours very truly,

A. S. E. ACKERMANN, B.Sc. (Engineering).

25, Victoria Street, Westminster, S.W.

May Meetings of the Junior Institution of Engineers.—The following meetings have been arranged for May by the Junior Institution of Engineers: May 9th, at 39, Victoria Street, S.W., discussion on "The Mechanical Lubricator as adapted to the Locomotive," introduced by Mr. W. N. Spratling. May 16th, at 39, Victoria Street, S.W., discussion on "Electrical Propulsion of Ships," by Mr. W. P. Durtnall, illustrated by lantern. May 21st, at 8 p.m., at the Institution of Electrical Engineers, Victoria Embankment, paper on "Heat Accumulators and their use in Exhaust Steam Turbine Plants," by Mr. A. Alison. May 23rd, at 39, Victoria Street, S.W., discussion on "The Organisation of an Engineer's Employment Bureau," introduced by Mr. S. H. Hills. May 24th, at 3 p.m., visit the King George Reservoir at Chingford. May 30th, at 39, Victoria Street, S.W., lantern lecture on "A Trip up the Meuse," by Mr. H. P. Philpot.

INDUSTRIAL AND TRADE NOTES.

The Dee Hydro-electric Power Plant.—The Dee Hydro-electric scheme, which is being carried out by the Chester Corporation in accordance with the proposals of Mr. S. E. Britton, the City Electrical Engineer, is expected to be in operation in July.

British Consular Service and Trade.—The advisory committee of the Commercial Intelligence Branch of the Board of Trade have issued a report dealing with the extent and nature of the services rendered by British Consuls to British trade with foreign countries during the past three years.

South Wales Tinplate Trade.—In South Wales the tinplate industry is passing through a severe crisis. As compared with February last year, there are at the present time eight works closed down, 73 mills idle, and 3,180 workers unemployed, with the prospect of further stoppages. Mr. Griffiths, the men's organiser, says: "I never remember trade in such a deplorable condition. Several mills have been closed down for months, and there is no sign of improvement."

Petroleum Production of Japan in 1912.—H.M. Embassy at Tokio reports that, according to the latest information obtainable, the output of crude petroleum in Japan during 1912 was roughly 57,168,300 galls. The figures for the production of refined oil in 1912 are not yet available. It is thought that the output of crude oil in 1913 will be about equal to that of 1912. The introduction of rotary boring has given a stimulus to the Japanese oil industry, which had been somewhat on the decline.

Water Power in Sweden.—According to a report from H.M. Legation at Stockholm, great attention is being paid to the development of the water power of Sweden. The number of power stations in operation is said to be 144, of which four are of more than 20,000 h.p., and the total horse-power produced amounts to 675,000. Three large hydro-electric power stations are being built for the State at Trollhattan (60,000 h.p.), Elfkarleby (45,000 h.p.), and at Porjus (50,000 h.p.). The total amount of water power available in Sweden is estimated at from 4,000,000 h.p. to 6,000,000 h.p.

Petroleum Industry of Mexico in 1912.—H.M. Legation at Mexico City, in a recent report, states that the total production of crude oil in Mexico in 1912 amounted to 16,704,731 barrels (of 42 United States gallons), or 2,493,244 metric tons. There is a possibility of these figures being increased by 100 per cent. during 1913. Few new fields have been developed during 1912, the chief discovery being the Chila Salinas Field (about 15½ miles south west of Tampico). During the year an 8in. pipe line from Potrero del Llano to Tuxpam was completed, and oil successfully delivered to steamers at the rate of from 25,000 to 30,000 barrels daily. Tankage facilities were considerably increased, principally at Tampico, Tuxpam, and Potrero del Llano.

Clyde Shipbuilding.—The vessels launched from Clyde shipyards during April make the second largest total on record for one month, and the four months' figures are the highest yet reached. The April total of 27 vessels of 119,303 tons is exceeded only by that of June, 1906, when the output consisted of 36 vessels of 124,544 tons. In that month, as in the past one, there were two notable vessels—the Cunard steamer "Lusitania" and the battleship "Agamemnon." Last month there was the Cunard steamer "Aquitania" and the Allan Line steamer "Calgarian." On the four months, however, there is a gain of more than 38,000 tons over the previous highest figures—those of last year—the total being 68 vessels of 237,161 tons, as compared with 88 vessels of 199,104 tons.

Messrs. Willans & Robinson, Ltd.—The report of Messrs. Willans and Robinson, Ltd., Rugby, for the half-year ended December 31st last shows that after allowing £3,265 for depreciation, £5,176 for debenture interest, and £372 for the upkeep of the Queen's Ferry Works, the profit amounted to £154. The report states that this improved trading result is mainly due to the increased volume of work referred to in the last report. During the opening months of the present year a large volume of further orders has been obtained and at somewhat better prices, a result largely attributable to the improved position of the company in anticipation of the re-arrangement of capital and its attendant advantages. The debit balance brought forward at June 30th, 1912, is reduced by the above profit from £85,964 to £85,810. The managing director states that the directors are raising additional preference capital, to which the existing shareholders are entitled first to subscribe.

Signalling in Coal Mines.—An effort to secure an improved system of signalling in coal mines is at present being made by the Scottish Colliery Engine and Boiler Men's Association. The object is to have the provision of a signal indicator in colliery winding engine houses made compulsory through the general regulations.

Mr. Robert Shirkie, secretary of the association, brought the matter before the Home Office some time ago, and, acting on a suggestion by the Home Secretary, he raised the subject at a meeting with the coalowners recently held in London, with the result that the employers agreed to have this safeguard inserted in the general regulations and made compulsory under the Coal Mines Act. It is stated that the new signalling code will probably be submitted to a referee appointed by the Home Office. An effort is being made to introduce a uniform code throughout the country, but the draft regulations which have been issued for this purpose are meeting with opposition both from enginemen and coalowners.

Accidents in Metal Mines in the United States.—According to A. H. Fay, mining engineer of the U.S. Bureau of Mines, 165,979 men were employed during the calendar year 1911 in the metal mines in the United States. Of this total 695 were killed, representing a rate of 4·19 per 1,000, as compared with 3·73 per 1,000 for the coal mines of the country in the same period. The serious injury cases amounted to 4,169, or 25·12 per 1,000 persons, and the slight injuries were given as 22,408, or 135·01 per 1,000. Of the total fatalities, 532 were underground (at the rate of 5·18 per 1,000 persons) and 153 were on the surface (at a rate of 2·49 per 1,000). Of the fatal accidents, 32·5 per cent. were due to falls of ore or rock from roof, wall, or bank; 11·23 per cent. were due to explosives, 15·39 per cent. to falling down stopes, shafts, or winzes, and 5·32 per cent. to fire. Of the serious accidents, 28·86 per cent. were due to falls, 19·05 per cent. to car and hauling systems, 12·19 per cent. to machinery, and 6·41 per cent. to timbers and hand tools. Among the slight accidents, 28·86 per cent. were due to falls, 15·52 per cent. to car and hauling systems, 7·10 per cent. to machinery, and 8·02 per cent. to timbers and hand tools.

Trade Unions and Co-partnership.—In the course of a discussion arranged by the Labour Co-partnership Association on the question of profit-sharing and co-partnership which took place a few days ago in London, Sir William Lever said the subject of profit sharing lay at the basis of very much of what manufacturers had to deal with in their business. Co-partnership should take the place of the old personal interest which an employer took in his men when businesses were smaller. At the present time trade unions viewed all co-partnership schemes with distrust. In his opinion the trade unions had just as much right to represent the men as any body of masters to represent masters, and they certainly found the great body of the men looking at co-partnership with something like suspicion. One reason for this seemed to be their idea that if the employer gave the men a share in his profits he was going to get it back in some way. It was perfectly possible, in his opinion, for a business to be run on strict trade union lines, with trade union pay, trade union hours, and trade union conditions throughout, and still be carried through on co-partnership principles. At the same time there was no room for philanthropy in business. The notion that a man could take his profits and divide them equally among his men was futile. It was the profit sharers themselves who must make the profits.

Shortage of Coal and Fuel Oil in Russia.—A debate recently took place in the Duma on the scarcity in the supply of Russian coal and fuel oil, during which it was emphatically denied that the State desired to establish a monopoly of the production of oil fuel. At the same time, the Minister of Commerce expressed himself in favour of the State working sufficient wells to supply its own requirements, for the State railways at first, and later on perhaps for the Navy, and remarked that it was proposed to organise a State industry in the Sabuntchinski region to supply the needs of the railways. He did not consider that the duty-free admission of foreign petroleum would ease the situation, which he thought could best be done by diminishing the demand for oil by substituting coal, the yield of which can be made to increase. Efforts are being made to enlarge the present limited use of anthracite, of which enormous supplies exist in Russia. Feeding and subsidiary railways are to be constructed in the Donetz region, where huge deposits remain unworked for want of easy means of communication. Railway rates are also to be reduced in order to attract coal from other districts. The Minister of Commerce stated that the Government was strongly opposed to any permanent remission of the import duties on foreign coal, but it had decided to allow the railways to import foreign coal duty free for a given period and a Bill to give effect to this decision would shortly be submitted to the Duma.

By-Product Coking.—Yorkshire is the second coke producing county in England, the tonnage produced only being exceeded by that of Durham. In 1911 there were in operation in Yorkshire no fewer than 3,539 beehive ovens, dealing with approximately 2,000,000 tons of coal during the year. The enormous waste thereby involved owing to the loss of the valuable by products—tar, sulphate of ammonia, and benzol—is a fact much to be regretted. It is pleasing to note, therefore, that at many collieries beehive ovens are being abolished and the modern type of by product recovery ovens erected in their stead. The Lowmoor Company, Lowmoor, near Bradford, a very old-established firm of ironmakers, are just making the change from beehive to by-product ovens. The installation is to consist in the first instance of a battery of 25 Koppers' regenerative ovens. In addition to the ovens, the plant is to include a by product plant for extracting tar and for producing sulphate of ammonia by Koppers' direct recovery process. A benzol plant is also to be erected for the production of crude benzol, and the whole is arranged for subsequent extension, the by product plant in the first instance being made capable of dealing with the gases from 50 ovens. The Tinsley Park Colliery Company, Ltd., of Sheffield, already have a battery of Simon Carves' recovery ovens at work. They are, however, making further additions to their coking plant, and are now installing a battery of 40 Koppers' regenerative ovens, complete with by product plant (for dealing with the gases from 50 ovens), for extracting tar and for producing sulphate of ammonia by the direct process, and also a plant for the recovery of crude benzol.

Shipbuilders' Wages Ballot.—An important circular dealing with the wages question was issued on Monday last week to the members of the trade unions employed in the federated shipbuilding districts. The circular states that at all the conferences the employers strongly urged that they had reached the apex of the present prosperity, that freights were distinctly lower, and that there was a decrease of enquiries. They further contended that the cost of production had increased so greatly that they were not able to execute work at remunerative prices. They also complained of the time lost by the workmen. This, they stated, was not only a loss to the firms, but was also a hindrance to the completion of work on hand, and they suggested that this request for an advance should be postponed for three months, when they were satisfied that it would be seen clearly that the application should not be enforced. The representatives of the trades, on the other hand, urged strongly that the industry showed no signs of decline, that the tonnage under construction was never greater, that the demand for labour was unprecedented in the history of the trade, that freights were still firm, and that, further, the cost of living had increased to such an extent that the purchasing power of a sovereign had been reduced by more than 15 per cent., with the result that the workmen were really in a worse position, notwithstanding the increases granted, during 1911 and 1912; while in many trades, notwithstanding the abounding prosperity in shipbuilding industry, rates were no higher than they were 15 years ago. Notwithstanding all the arguments advanced by the men's representatives, however, the employers would not agree to their request, and the men's representatives, in considering the position, informed the employers that they had failed to convince them, and that in their opinion the reasonable request of the men should be conceded. The members of the societies are asked therefore to vote on the following propositions: (*a*) For accepting the employers' proposal to adjourn the request for three months. (*b*) For giving notice to cease work to obtain the advance asked. The results of the voting are to be returned to the secretary of the Standing Committee on or before May 29th. When the pooled result is obtained the committee will then lay the matter once more before the Employers' Federation, and also—if the figures are in favour of a stoppage of work—decide when such stoppage shall take place—that is, if any further negotiations that may be held with the employers fail to settle the dispute.

METAL QUOTATIONS.

TUESDAY, MAY 6TH.

Aluminium ingot	95/- per cwt.
,, wire, according to sizes, &c. ......from	112/- ,,
,, sheets ,, ,, ... ,,	120/- ,,
Antimony ....£32/-/- to	£33/-/- per ton.
Brass, rolled	8⅝d. per lb.
,, tubes (brazed)	10½d. ,,
,, ,, (solid drawn)	9d. ,,
,, ,, wire	8⅞d. ,,
Copper, Standard	£69/10/- per ton.
Iron, Cleveland	67/3 ,,
,, Scotch	73/3 ,,
Lead, English	£18/17/6 ,,
,, Foreign (soft)	£18/8/9 ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/10/- per bottle.
Silver	27⅜d. per oz.
Spelter	£25/7/6 per ton
Tin, block	£230/10/- ,,
Tin plates	14/3 ,,
Zinc sheets (Silesian)	£28/10/- ,,
,, (Stettin; Vieille Montagne)	£28/12/6 ,,

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Manufacture of armour plates and other steel articles. Vickers, Ltd., and Benthall. 885.
Tube cleaners. Hall. 1532.
Acetylene gas generators. Calvo. 7283.
Balancing of rotating masses. Soc. Anon. pour L'Exploitation des Procédés Westinghouse Leblanc. 8527.
Internal combustion engines. Cochrane. 8625.
Pneumatic clutches for transmitting power. Prather. 8631.
Carburetters for internal combustion engines. Dürr. 8784.
Method of fixing blades of turbines. Knight. 8785.
Centring device for shafts. Gabriel. 8819.
Water-tube boilers. Parsons & Cook. 8850.
Variable speed transmission gearing. Ross, and Ross Transmission Gear Company. 8981.
Acetylene gas generators. Shepherd & Haworth. 8999.
Driving belts. Sleigh. 9088.
Means for use in starting internal combustion engines of automobiles. Wolseley Tool and Motor-car Company, Remington, and Rowledge. 9113.
Liquid meters. Kent. 9197.
Nut lock. Phillips & Phillips. 9274.
Means for grinding in valves. Griffin. 9431.
Automatic car couplers. Willison. 9622.
Furnaces. Baird & Warrand. 9692.
Means for feeding blanks to turret lathes. Rindfleisch. 9947.
Appliance for automatically supporting a pit cage in safety should the haulage rope break. Nunn & Hanks. 10200.
Turbines. Walker. 10300.
Blastfurnaces. Rogerson. 10399.
Machine for washing or separating coal, ore, and other granular materials. Benson, and Head, Wrightson, & Co. 10929.
Meter for use with liquid fuels. Hudlass. 11278.
Wire drawing. Deutsche Gasgluhlicht Akt. Ges. 11439.
Power operated capstans. Conradi. 12166.
Pneumatic brakes. Chapsal & Saillot. 12858.
Carburetters for internal-combustion engines. Charlton. 12890.
Water-cooled system for internal-combustion engines. Dalman. 13148.
Valve for regulating pressure on brake engines. Bell & Graham. 13677.
Marine boiler furnaces. Carew. 14382.
Mechanical cooling beds for rolling mill trains. Rombacher Huttenwerke. 15422.
Automatic couplings for railway wagons. Bradbury. 15996.
Method of and apparatus for preventing the spreading and effect of coal dust and firedamp explosions. Kahler & Junker. 16140.
Box spanners. Delacroix. 16793.
Overhead travelling cranes. Steel Nut & Joseph Hampton, Ltd., and Merrell. 17183.
Regulating and reversing apparatus for regenerative gas furnaces. Kopper. 17732.
Pumps for raising and forcing cement and other semi liquids. Bailey & Bailey. 17796.
Control of dampers in steam generating plant. Wood, Braddock, and Pickford. 19157.
Boring and facing machines. Pearn. 19159.
Treatment of metals or alloys to render them ductile and malleable. Westinghouse Metallfaden Gluhlampenfabrik Ges. 19288.
Internal combustion engines. Neumann. 19333.
Driving belts. Gray. 19860.
Valves for pumps. Dickson. 20602.
Supply of air for furnaces. Hill. 20643.
Steam generators. Makin. 20691.
Internal combustion engines. Pearson. 22138.
Arrangement of two stroke cycle internal combustion engines for ships. Kilburn. 23011.
Method for revivifying or restoring permutit. Schweikert and Czeczowiczka. 23706.
Tractors. Cook & Van Tuyl. 23746
Aeroplane. Westerman. 24227.
Lifting jacks. Aron & Benstead. 24627.
Cranes. Imray. 24669.
Explosion turbine. Andersen. 24679.
Gas producers. Simonenko & Hendunen. 25778.
Aerial machines. Blériot. 25877.
Die stocks. Martignoni & Jäger. 26047.
Clutches. Soc. Anon. des Anciens Etablissements Panhard and Levassor. 26137.
Pressure regulating valves. Regondi. 26790.
Rolling-mills. Smith & Huntbatch. 26838.
Acetylene gas generators. Allen, and Allen Liversidge Portable Acetylene Company. 27308.
Device for bending iron pipes. Huber. 27849.

1913.

Strainers for use in the suction pipes of pumps. Westbrook. 471.
Thrust bearings. Johnston. 2888.
Ball bearings. Debois. 3085.
Steam generators. Aitken. 7939.

ELECTRICAL, 1912.

Electric storage systems. Kettering. 3791.
Transformation of direct currents. Akt. Ges. Brown, Boveri, et Cie. 6550.
Combined intercommunication and party line telephone systems. Sterling Telephone and Electric Company. 6580.
Electric arc furnaces. Marks. 8791.
Telephony. Brown. 9179.
Electric cables. Western Electric Company. 9309.
Synchronous dynamos. Rosenberg. 9644.
Phase compensation of dynamo-electric induction machinery. Akt. Ges. Brown, Boveri, et Cie. 10113.
Electric flame arc lamps. Schuer. 10496.
Supporting of insulators for electric conductors. Marks. 10805.
Metallic filaments for incandescent electric lamps. Scoular, and Dick, Kerr, & Co. 11455.
Electric switches for multiple unit control systems. Turner. 13740.
Receivers for printing-telegraph systems. Hiltz. 14831.
Electric brakes for tramway vehicles. Turner. 15023.
Telegraphic apparatus. Knudsen. 15591.
Electric switches. British Thomson-Houston Company, and Wallace. 15776.
Filament holders for metal filament electric incandescent lamps. Baum. 16865.
Magnetic speedometers. Stewart. 17942.
Electrometers and appliances for indicating and measuring variations in electric potential. Maurice. 18065.
Electro magnetically operated switches. Schattner. 20247.
Electrical protective apparatus. De Stefani. 22129.
Time lag devices for electric switches. Railing, Strachan, and Coates. 22509.
Electric discharge apparatus. Majorana. 23024.
Parallel working of synchronous machines. Marks. 24097.
Setting the timing gear of electrical-ignition systems. Sturgeon. 26143.
Circuit arrangements for the reception of signals transmitted by means of electromagnetic waves. Imray. 28070.
Electric current transformers. Wescott. 28967.

1913.

Hot wire electrical measuring instruments. Siemens Bros. and Co. 943.
Telephone systems. Sterling Telephone and Electric Company. 7593

The Uses of Alundum.—In the course of a lecture before the Massachusetts Institute of Technology by Mr. K. E. Herrick, of the Norton Manufacturing Company, he referred to the laboratory applications of alundum, which is chiefly used as an abrasive. This material is an artificial oxide of aluminium. The latter is produced from a mineral, bauxite, which is a hydrated oxide of aluminium found in the southern portions of the United States and also in Europe. Domestic bauxite is first calcined and then melted in electric furnaces. The impurities, consisting mostly of metallic oxides, and the pure alumina—Al_2O_3—are removed in immense ingots weighing about 5 tons each. These are broken up and shipped directly to Worcester. There they are ground, mixed with a binder, and burned in a kiln. The final product is alundum, which gives great promise of revolutionising certain processes in the chemical laboratory. One of the important properties of alundum is its high refractive power, and in this respect it is far superior to ordinary porcelain. It has also a low coefficient of expansion, and will endure very rapid heating and cooling. It furthermore pessesses very fair thermal conductivity. Chemically it is a very inert substance, and although it cannot be employed as a complete substitute for platinum, in crucibles, it is an excellent supplement to the latter material. Alundum has also been employed as an inactive lining for electric furnaces. What seems to be the most important use for this material is its application to filters, which is a consequence of its porosity. Alundum filters have been on the market only a few months, but are said to be superior to the time-honoured asbestos filters.

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Edited by
WILLIAM H. FOWLER
Wh. Sc., M.Inst.C.E.

Telegrams: "Scientific," Manchester.
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Iron and Steel Works Practice.

There is something about the meetings of the Iron and Steel Institute not usually found at those of kindred institutions. Popular tradition pictures the ironmaster as a man of strong character, large organising capacity, and wide-stretching outlook in the affairs of his business. There is no mistaking him for the wealthy tradesman, the eminent professional man, or even for the modern director of an engineering company; although some of the older engineering masters had something of the same singleness of purpose and determination of spirit. Popular tradition, no doubt, colours the picture a little too highly, but there is some truth in its verdict. Even in these days of limited companies, with their numerous shareholders and changing boards of directors, the men who count in our iron and steel industries still possess some of the characteristics outlined above, and these characteristics are reflected in the discussions over the papers at the Iron and Steel Institute. At the back of the mind of the iron or steel master is always the market, and technical problems are continually viewed from the market standpoint. No doubt this is encouraged by the nature of their products. There is a tremendous range of iron and steel products, but the bulk of them, apart, of course, from the special manufactured articles of engineering and allied trades, belong to two classes, in each of which there are few divisions; although not, perhaps, rigidly defined. Thus the ironmaster makes pig iron, and, whilst it is true that there are many varieties of pig, the bulk of the pig iron smelted falls into a few divisions, to one or two of which the individual ironmaster confines himself. If he is the maker of, say, a West Coast hematite his market is very closely defined, and it is an easy matter for him to watch its changes and to estimate its influence on his fortunes. Similarly, the steelmaster finds it moderately easy to read the markets for boiler and ship-plates, merchant-bars, or tin-plates, and he, too, has his attention continually diverted to the broader aspects of the industry. In engineering it is more difficult to read the

market. In the first place prices are rarely published, and even if they were the wide variety of work would minimise their importance. Thus it comes about that engineers tend to leave the market and wider economic considerations out of their discussions at their Institution meetings, and in the popular estimation they are set down as provincial in outlook.

Engineers, do, however, take an interest in their markets, even if they are little inclined to discuss them. One of these markets is supplied by the iron and steel industries, and it is interesting to note the tendency of practice in this market. The British iron and steel industries have not progressed very rapidly on their engineering side for some years past. Blowing-engines for blastfurnaces are still mainly of the plain simple-expansion types, and it is only here and there that compound engines using superheated steam, and being generally of an economical type, are to be found. The turbo-blower has made a little headway, but the inefficiency of the blower itself prevents it from being a formidable competitor where the highest economy of steam is desired, and where this is not sought the feeling of blastfurnace managers seems to be in favour of the well-tried reciprocating engine. The explanation of this attitude is very largely the isolation of our blastfurnaces. Some are connected with steel works, but many stand alone. The gases from the furnaces supply the stoves and the boilers for these uneconomical engines. If more economical types are installed they would probably cost more to instal, and the ironmaster sees no market for his surplus gas. On the other hand, competition is steadily forcing blastfurnace owners to seek a market for their surplus gases. If utilised in the most economical manner the heat in the surplus gases, after supplying the stoves and gas-driven blowing- and auxiliary-engines, is equivalent to rather more than a quarter of a ton of coal per ton of pig smelted. Looked at in this light the loss to the ironmaster is two or three shillings per ton of pig. If a steel works is at hand the surplus gas can be used in the furnaces and in engines, and as this forms a natural market for the gases present tendencies are all towards combining blastfurnaces and steel works. If this market is not available others should be sought. Another tendency is noticeable at present. Many furnaces are now making their own coke in regenerative by-product ovens. Apart from the by-products the surplus gas contains about seven or eight per cent. of the original heat in the fuel. Moreover, this gas is of four or five times the calorific value of blastfurnace gas, and is much more suitable for furnace work. Hence, either alone or mixed with the blastfurnace gas, it is extremely useful in a steel works.

The efficient utilisation of the surplus gases is assisted by the employment of large gas engines for driving the blowing-tubs and generating what electricity may be required. In some of the new works, both in Europe and America, the whole of the rolling mills and auxiliary machinery is electrically driven, the current being generated by large gas engine-driven alternators using surplus blastfurnace and coke-oven gases. In some cases such gases supply the whole of the power and also all the heat required in the works, with, of course, the exception of the coke for the blastfurnaces themselves. In the majority of cases, however, steam rolling-mill engines are retained. Until quite recently, the steam consumption of these engines was but little considered. In most instances the engines were simples and often non-condensing. A few were compound, and some exhausted into a condenser, which was usually of too small a capacity and gave a poor vacuum. In nearly all cases the boiler-pressure was low and superheat not used. According to Dr. Puppe's paper on "Rolling-Mill Practice in the United States," recently read before the Iron and Steel Institute, this condition of affairs still holds in America, as it does, substantially, in this country. In Germany great efforts have been made to improve the economy of reversing rolling-mill engines. Two lines of attack are followed. Compound engines are employed so far as possible, and superheat is usual. Moderate pressures are employed, although there are operating objections to too high a boiler-pressure, and the engines operate condensing, or, occasionally, exhaust into a low-pressure turbine. In this way economy is ensured so far as the general type of engine can do it. The other line of attack is to enforce that the engine shall, so far as possible, be operated in the most economical manner consistent with ease of handling and maintenance of output. This necessitates so arranging the control gear that there is only one method of control normally possible, and hence the two-control handles have given place to one. Several continental firms have developed single-lever control gears with this object in view, but so far very little has been done in this country to that end; although there are signs that the importance of this matter of control is now being recognised, and it is highly probable that the future will see considerable changes in rolling-mill engines. Certainly all the signs point towards a campaign in favour of economy, and whilst the importance of output must not be lost sight of, it is becoming more evident that means must be found of combining maximum output with maximum economy of operation.

The importance of output has been mentioned, and judging from Dr. Puppe's paper, referred to above, and an earlier paper by the same author, the importance of a large output is set almost above everything else in the United States, where in some cases the output from a rail-mill reaches 4,000 tons a day of 24 hours, and similarly striking figures are quoted for billet and other mills. The most striking results in this direction are not obtained on the smallest sections nor on the more finished products, as it is found necessary to limit the finishing temperature, draught of section, and speed of rolling. Exactly what the limits are is not known, but they are pushed further in America than in Europe and the tendency seems rather to follow the American practice as far as possible. Certainly engineers in designing rolling-mill engines and the mills themselves should take account of this tendency and provide for higher speeds of rolling and larger turning moments. There is no finality in engineering practice; and therein lies its great charm.

Institution of Civil Engineers: Election of Officers.—At the annual general meeting of the Institution of Civil Engineers held on Tuesday evening, April 29th, the result of the ballot for the election of officers was declared as follows: President, Mr. Anthony George Lyster, M.Eng. (London); vice-presidents, Mr. Benjamin Hall Blyth, M.A. (Edinburgh), Mr. John Strain (Glasgow), Mr. George Robert Jebb (Birmingham), Mr. Alexander Ross (London); other members of Council: Mr. John A. F. Aspinall, M.Eng. (Liverpool), Mr. John A. Brodie, M.Eng. (Liverpool), Mr. William B. Bryan (London), Col. R. E. B. Crompton, C.B. (London), Mr. J. M. Dobson (London), Sir Hay Frederick Donaldson, K.C.B. (London), Mr. E. B. Ellington (London), Mr. W. H. Ellis (Sheffield), Mr. W. Ferguson, M.A., B.A.I. (Australasia), Sir Maurice Fitzmaurice, C.M.G. (London), Sir John Purser Griffith (Dublin), Mr. C. A. Harrison, D.Sc. (Newcastle-on-Tyne), Mr. Walter Hunter (London), Mr. Harry E. Jones (London), Sir Thomas Matthews (London), Mr. W. H. Maw, LL.D. (London), Mr. C. L. Morgan (London), Mr. Basil Mott (London), Mr. A. M. Tippett (South Africa), Sir Philip Watts, K.C.B. (London), Mr. W. B. Worthington, B.Sc. (Derby), Mr. Dugald Clerk, F.R.S. (London), Mr. Robert S. Highet (India), Mr. Edward Hopkinson, M.A., D.Sc. (Manchester), Mr. Frederick Palmer, C.I.E. (London), Mr. H. N. Ruttan (Canada). This Council will take office on the first Tuesday in November, 1913.

BOOK REVIEWS.

Practical Alternating Currents and Alternating Current Testing, by Chas. F. Smith, M.Sc., M.I.E.E., &c. Fifth edition. Manchester: The Scientific Publishing Company. 8¾in. by 6in.; 397 pp.; price, 6s. net.

The appearance of a fifth edition of this well-known work within a comparatively short period is perhaps the best testimony of its excellence and of the extent to which it meets the wants it is designed to fulfil. The popularity of the work is no doubt due in large measure to the comprehensive and at the same time comparatively simple way in which the author deals with the mathematical problems associated with alternating current work and which in less skilful hands usually involves a forbidding use of the higher mathematics. His experimental method of treatment is also one that appeals strongly to the engineer as well as to the student, especially as the experiments are so carefully described that the conclusions derived from them may be followed and accepted by the reader in cases where he has not the means of conducting them himself. To those who have access to practical laboratory work they form an excellent outline for a course of study, and their careful graduation has no doubt contributed largely to the popularity of the work with teachers as well as with students.

Reinforced Concrete Bridges, by Fredk. Rings. London Constable & Co. 11in. by 8in.; 181 pp.; price, 21s. net.

The main advantage of this work to the engineer lies in the careful and elaborate discussions of constructional details of bridge work taken from actual practice. It is a class of information of which the draughtsman and designer is often sorely in need in approaching fresh designs and which as a rule is difficult to obtain. The series of examples taken for the purpose of illustration are not perhaps the most striking of reinforced concrete construction, but they are not on that account less lacking in the essential principles of construction, while no complaint can be made of the lack of variety or type. To those interested in this rapidly-growing field of construction the book is one that should prove very useful.

Single-phase Commutator Motors, by F. Creedy, A.M.I.E.E., &c. London: Constable & Co. 8¾in. by 5½in.; 113 pp.; price, 7s. 6d. net.

As a monologue on single-phase motors this little work will doubtless meet with an appreciative though possibly somewhat select class of reader. Its main merits consist of the graphic vector methods of analyses by which the actions of this type of motor are reduced to numerical forms which the reader can easily grasp, but the price strikes us as being stiff in comparison with the general run of electrical technical literature.

Modern Pumping and Hydraulic Machinery, a Practical Handbook for Engineers, Designers, and others, by Ed. Butler, M.I.Mech.E., with 345 illustrations. London: Chas. Griffin & Co. 9in. by 6¾in.; 473 pp.; 18s. net.

The author of this comprehensive manual will be known to many of our readers in connection with the series of articles on pumping machinery which appeared in our columns some time ago, and the subject matter of which forms largely the basis of the volume before us. The main value of the book to the engineer lies in the extraordinary wealth of sectional views with which the subject is illustrated, and which include almost every type of pumping appliance in existence, coupled with the detailed descriptions and actual performances. To all actively interested in pump construction or working, the book should prove of value.

BOOKS RECEIVED.

Elements of Heat-Power Engineering. By C. F. Hirshfeld and Wm. N. Barnard, Professors of Engineering, Sibley College, Cornell University, Ithaca N.Y. New York: J. Wiley & Sons; and London: Chapman & Hall. 9¼ by 6½, 811 pp. Price 21s. net.

A Text Book of Experimental Metallurgy and Assaying. By A. R. Gower, F.C.S. London: Chapman & Hall, Ltd. 7½ by 5, 163 pp. Price 3s. 6d. net.

Steam Engineering. By W. R. King, Principal, Baltimore Polytechnic Institute. New York J. Wiley & Sons. London Chapman & Hall, Ltd. 9½ by 6, 450 pp. Price 17s. net.

Machine Construction and Drawing. By A E. Ingham, Lecturer in Engineering, Technical Institute, Altrincham London: G. Routledge & Sons, Ltd. 8½ by 5½, 113 pp. Price 1s. 6d. net.

Gas Power. By C. F. Hirshfeld, Professor of Engineering, Sibley College, and T. C. Ulbrecht, Lecturer in Engineering, Sibley College. New York: J. Wiley & Sons, and London Chapman & Hall, Ltd. 7¾ by 5½, 209 pp Price 5s. 6d. net

A Handbook on Japanning, for Ironware, &c. By W. N Brown. London: Scott, Greenwood, & Son. 7½ by 5, 66 pp Price 3s. 6d. net.

Modern Steam Boilers (the Lancashire Boiler). A Practical Manual. By W. D. Wandsbrough. London: Crosby Lockwood & Son. 8¾ by 5¾, 156 pp. 4s. 6d. net.

Board of Trade Instructions for the Survey of Passenger Steamships. London: Wyman & Sons. Price 6d. net.

Journal of the Institution of Electrical Engineers, April, 1913. Vol 50. London: E. & F. N. Spon. Price 5s. net.

The Sling and Its Story: Remarks in connection with lectures delivered at the Royal Institution by W. Leighton Jordan. London: Simpkin, Marshall, Hamilton, Kent, & Co., Ltd. 8¾in. by 6in, 421 pages. Price 7s. 6d. net.

Gas-engine Principles. By Roger B. Whitman. New York and London: D. Appleton & Co. 7½in. by 5in., 248 pages. Price 6s. net.

Journal of the Textile Institute. Edited by T. W. Fox and J. Hubner. Vol. III., No. 2. Manchester: 14, Cross Street.

ZOELLY'S OIL ENGINE.

In an internal-combustion engine in which the combustion takes place under approximately constant pressure it has already been proposed to rapidly inject the combustible into the air charge in the cylinder, and to ignite it by a continuous electric igniter therein, such as incandescent igniting wires or a continuous spark, while further it has been proposed in an internal-combustion engine of the continuous combustion type to compress a charge of air and to then admit gas compressed to a higher pressure, the gas being ignited as it enters by a glowing wire. In the uniform pressure internal-combustion engine, illustrated herewith, the invention of H. Zoelly, Hardturmstrasse 19, Zürich, Switzerland, the compression of the air is also not carried to the point where the ignition temperature of the fuel is attained, and the heat still required towards attaining such temperature is supplied to the combustible charge in the combustion chamber by an electrically heated body, having a large external surface past which the combustible charge is conducted. In some cases the combustible charge or a constituent thereof is led through an electrical spark gap. In this way combustion is ensured throughout the entire admission period.

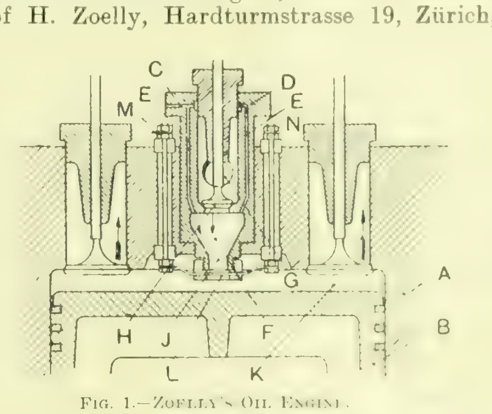


Fig. 1.—Zoelly's Oil Engine.

Referring to Fig. 1, which shows the upper part of a vertical two-cycle internal-combustion engine, A is the cylinder and B the piston located therein. The fuel, oil for example, is introduced by means of a pump, through an opening C in a sleeve D. The oil which is supplied at the required pressure flows through small passages E into the

mixing chamber F. The air is supplied through a port G, and the supply is controlled by means of a valve H, through which it enters the mixing chamber F. From the mixing chamber the air, conjointly with the oil flowing through the ports E, passes at a comparatively high velocity through an opening J into the cylinder chamber K. L is an electrical heating device so arranged in front of the opening J that all the mixture of air and gas passing through this opening into the cylinder chamber K passes through the heating device. The heating device may be constructed of wire gauze or wire bent sinuously, as shown in elevation to a larger scale in Fig. 2. In this construction a wire, insulated from the casing, is embedded in porcelain and connected at its ends to terminals M and N passing through the cylinder cover, as shown in Fig. 1. The mixture of fuel and air is heated to the desired temperature by contact with the comparatively large area of the wire O in Fig. 2.

Fig. 3 illustrates a construction in which a long spark is used for heating the mixture of fuel and air. In this arrangement current flows by means of terminal Q to the electrode R across the spark gap to electrode S, and thence to terminal T. In this construction the fuel flows through the nozzle controlled by means of the needle valve U, and is heated on its passage through the spark gap, across which the electric sparks pass at right angles to the direction of flow of the fuel. The air flows through the two valves V and W, and mixes with the fuel, which has become heated

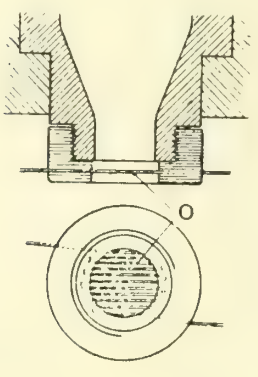


FIG. 2.

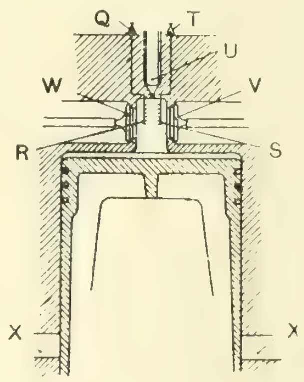


FIG. 3.

ZOELLY'S OIL ENGINE.

in its passage across the spark gap. Above the piston chamber proper there is a special heating chamber which is made of comparatively small cross-section, so that the freshly-entering air may continuously propel the mixture already produced forwards into the cylinder, and thereby ensure that the freshly-arriving fuel shall come into intimate contact with the spark gap and mix with fresh air, thus preventing the spark gap from being isolated by any residual mixture or any burnt gases remaining from the last cycle. This arrangement ensures that the vicinity of the spark gap is always well prepared during the admission period for efficiently heating the freshly-arriving fuel. The exhaust of the burnt gases takes place through ports X.

Since the heating is effected by the giving up of electrical energy, an engine of this kind, in contradistinction to a Diesel motor, does not need to compress to such a high degree, and can therefore work on the whole at considerably lower pressures. The air and fuel may be pre-heated by the waste gases in any well-known way. Since also combustion is ensured throughout the entire admission period, this period may be long and a stroke pressure diagram, the abscissæ of which indicates the piston stroke or the time and the ordinates the pressure is of greater dimensions in breadth, and need not therefore be so high for a given area as in an explosion engine, or in a Diesel motor. This means that when the arrangement under notice is used for a given output, not nearly such high pressures as heretofore usual are necessary, and the parts can therefore be made lighter, while the arrangement, it is claimed, also permits of a much finer regulation and a more economical working, particularly in the case of partial loads.

THE INFLUENCE OF THE METALLOIDS ON THE PROPERTIES OF CAST IRON.*

BY H. I. COE, M.SC.

THE present research is intended as preliminary to one dealing with the effect of metals not usually present in cast iron on the iron carbon alloys, in order subsequently to ascertain by comparison the utility of adding those metals to cast iron. The general scheme of work involved an investigation of the effect of varying quantities of manganese, sulphur, and phosphorus on cast irons containing different proportions of silicon. The influence of varying total carbon was not considered, and it was endeavoured to keep that element as constant as possible, in the region of 3 per cent., though complete success in this direction was not attained owing to the diluting action of the ferro-silicon employed. The base used was American washed iron, which was melted under charcoal in a graphite crucible, and when melted the other elements were added in the form of suitable alloys.

Transverse bars, 15in. by 1in. by 1in. (tested on 12in. centres), and 9in. tensile bars, 6in. of which had a diameter of ¾in., were prepared. Since many of the bars were too hard to machine, all were tested as cast. The hardness, as determined by the scleroscope, often varied very considerably from the exterior to the interior. In order, therefore, to get relative results the hardness values were in all cases obtained from the polished surfaces of the transverse bars. Their actual value will have to be considered in connection with the remarks in Table I.

The Influence of Silicon on Cast Iron.—The influence of silicon on the condition of the carbon will be seen upon reference to Table I. Broadly, the results are in agreement with those given in recent papers by Hatfield, and by Hague and Turner, though the conditions as regards size of bar and total carbon content were slightly different, both factors tending to an increased separation of graphite in the present series. With the increasing separation of graphite the strength and hardness of the bars decreases, while the deflection fluctuates somewhat irregularly.

The Influence of Manganese on Cast Iron in the Presence of Silicon. — The influence of manganese on pure iron carbon alloys has been investigated by Wüst, by the author, and others, and it has been shown that in such cases the addition of manganese increases the stability of the carbide owing to the formation of a double carbide of iron and manganese, which does not readily decompose; a direct hardening effect is also observed. In the presence of 2 or 3 per cent. of silicon the effect is similar, though not so pronounced. The hardness is considerably increased, and the general effect of the addition of large quantities of manganese is to retain the carbon in the combined form.

A point of very considerable importance was observed by A. Hague and T. Turner, relative to the influence of a small quantity of manganese on a siliceous cast iron. 0·6 per cent. of manganese added to a cast iron containing 3 per cent. of silicon resulted in a considerable decrease in the percentage of combined carbon. The author investigated this point more fully, the results of the research being embodied in a paper to the British Foundrymen's Association (1910, Vol. II., page 163). It was found that the addition of manganese to a cast iron containing 2 per cent. of silicon, either in the presence or absence of phosphorus, resulted in a diminution of the percentage of combined carbon, with a corresponding decrease in hardness, this effect reaching a maximum with 0·5 per cent. of manganese. Further addition of manganese was accompanied by an increased percentage of combined carbon and increased hardness.

The cast irons examined in the present research were prepared in a different manner from those described above, but, nevertheless, the facts observed are in substantial agreement.

In discussing the influence of manganese there is another factor to consider, namely, rate of cooling. The fracture and the microstructure show that the chilling action of the

* Paper presented at the annual meeting of the Iron and Steel Institute, May, 1913.

sand is intensified by even small additions of manganese. The softening influence of the manganese is, however, observed on the unchilled interior of the bar. This softening influence of small quantities of manganese on siliceous irons is due to the precipitation of secondary graphite after solidification down to the pearlite arrest point. Evidence for this statement is found in shrinkage curves and photomicrographs that have been published.

Reference to Table I. shows that the addition of small quantities of manganese considerably increases the strength and deflection, the effect being more marked in those irons which in the ordinary cast condition are wholly grey. In the latter irons, also, the hardness is seen to fall with the addition of 0·5 per cent. manganese, and then to increase with further addition. It will be observed that while the hardness varies with the combined carbon, the strength is more influenced by change in structure.

The Influence of Sulphur on Cast Iron Containing Silicon.—The subject of the influence of sulphur on cast iron has attracted considerable attention of late years, and important researches dealing with it have been published, notably by J. E. Stead and D. M. Levy. Dr. Percy, in discussing work performed in his laboratory on the influence of sulphur on cast iron, states that "sulphur in certain proportions has the power of causing carbon to remain in the combined state during solidification after fusion." This statement has been fully confirmed by later investigators. At the same time, comparatively little is known of the effect of sulphur on the mechanical properties of cast iron, other than that it hardens the metal owing to its influence on the state of the carbon. Again, the general opinion is held that it renders cast iron brittle, though the author knows that some foundry managers realise the value of suitable proportions of sulphur in increasing the valuable mechanical properties of cast iron.

TABLE I.

	No.	Transverse Strength, 12″×1″×1″, Cwts.	Deflection, Inches.	Tensile Strength, Tons per sq. in.	Hardness Number	Total Carbon, Per Cent.	Graphitic Carbon, Per Cent.	Combined Carbon, Per Cent.	Silicon, Per Cent.	Manganese, Per Cent.	Sulphur, Per Cent.	Phosphorus, Per Cent.	Remarks on the Fracture
SILICON.	1	29·4	0·084	12·95	57	3·22	0·03	3·19	0·40		0·011	0·018	White and crystalline
	2	29·1	0·093	13·72	56·5	3·12	0·25	2·87	0·50	.		.	Slight central mottle
	3	25·3	0·100	10·06	58	3·04	1·77	1·27	0·80		0·013	..	White edges
	4	24·4	0·094	12·67	47	3·28	2·15	1·13	1·00	0·014		0·090	Narrow white edges
	5	22·0	0·098	9·03	49	2·80	1·61	1·19	1·11			.	Very slight chill
	6	23·5	0·162	9·03	47	3·05	1·95	1·10	1·31	.	0·011		,, ,,
	7	23·3	0·132	10·10	43	3·02	2·10	0·92	1·62	0·040	0·015	0·093	Light grey
	8	24·6	0·115		.	3·05	2·05	1·00	1·87	...	...		,,
	9	23·8	0·080	14·33	40·5	2·88	1·80	1·08	2·03	0·020		.	More open grain.
	10	20·0	0·080	9·92	45	2·79	1·73	1·06	2·24	0·016	0·016	0·027	,, ,,
MANGANESE.	11	29·8	0·080		59·7	3·08	0·46	2·62	0·58	0·784	.	.	White and crystalline
	12	34·7	0·093	15·50	58	3·22	1·09	2·13	0·82	0·350	.	...	Mottled centre
	4	24·4	0·094	12·67	47	3·28	2·15	1·13	1·00	0·014	.	0·090	Narrow white edges.
	13	32·0	0·098	13·28	50	3·30	2·25	1·05	1·00	0·050		.	,, ,,
	14	30·9	0·092	16·59	51·5	3·15	2·33	0·82	1·02	0·846	.	.	,, ,,
	15	33·0	0·103	16·35	65·5	3·08	1·07	2·01	1·03	2·000		...	White and crystalline.
	7	23·8	0·132	10·10	43	3·02	2·10	0·92	1·62	0·040	0·015	0·093	Light grey.
	16	24·0	0·132	14·93	31	3·19	2·89	0·30	1·52	0·541		0·027	Dark velvety grey.
	17	27·1	0·110	15·11	40	3·04	2·61	0·43	1·50	1·030	.		Corners white.
	18	28·2	0·148	18·16	42·5	3·20	2·42	0·78	1·69	2·220		...	Silvery grey.
	10	20·0	0·080	9·92	45	2·79	1·73	1·06	2·24	0·016	0·016	0·027	Light grey and open.
	19	20·8	0·133	12·12	31	3·05	2·83	0·22	2·25	0·611	...	..	Dark grey and close.
	20	21·6	0·129	15·48	38	3·11	2·64	0·47	2·29	1·023		.	Somewhat lighter.
	21	28·6	0·120	15·47	43	3·03	2·34	0·69	2·42	1·960		..	,, ,,
SULPHUR.	3	25·3	0·100	10·06	58	3·04	1·77	1·27	0·80		0·013		White edges.
	22	.		10·46	59	3·06	0·26	2·80	0·80		0·034	.	White, slight mottle
	23	35·4	0·114	...	60	3·13	0·33	2·80	0·78	.	0·060	...	,, ,,
	24	39·6	0·120	10·18	58	3·00	0·33	2·67	0·82		0·103	..	,, ,,
	6	23·5	0·102	9·03	47	3·05	1·95	1·10	1·31		0·011	.	Slight chill.
	25	32·5	0·116	13·28	50	3·16	1·45	1·71	1·35		0·050	.	Considerable chill.
	26	42·0	0·127	...	56	3·00	0·80	2·20	1·30	.	0·105	..	White, slight mottle.
	27	35·6	0·122		56	2·94	0·50	2·44	1·32	.	0·150		,, ,,
	28	39·6	0·122	13·05	61	2·91	0·40	2·51	1·17	...	0·193	...	Only centre mottled.
	7	23·8	0·132	10·10	43	3·02	2·10	0·92	1·62	0·04	0·015	0·093	Light grey.
	29	24·1	0·118	15·84	43	3·12	2·12	1·00	1·60		0·031	.	,,
	30	30·2	0·120	14·28	43	2·90	1·75	1·15	1·63		0·056	.	,,
	31	30·7	0·126		40	3·02	1·89	1·22	1·40	.	0·084	...	Corners chilled.
	32	28·9	0·127	8·84	43	3·09	1·95	1·14	1·57		0·090	.	,,
	33	26·7	0·096	14·50	49	2·94	1·69	1·25	1·52		0·103	.	Edges chilled.
	34	28·5	0·102	18·48	60	3·05	1·80	1·25	1·69		0·112	...	,,
	35	30·5	0·090	12·24	60	2·87	0·67	2·20	1·55	.	0·155	...	White, mottled centre.
	10	20·0	0·080	9·92	45	2·79	1·73	1·06	2·24	0·016	0·016	0·027	Light grey, open.
	36	27·9	0·114	13·04	45	2·90	1·84	1·06	2·24		0·104	..	,,
	37	35·7	0·150	19·71*	43	2·70	1·57	1·13	2·37	..	0·180	...	,,
	38	31·8	0·106	16·61	63	2·70	0·85	1·85	2·05	.	0·452	...	White edges, grey centre
	39	27·3	0·097	12·61	53	2·90	1·57	1·33	1·23	0·325	0·204	...	Chilled edges.
	40	29·0	0·125	14·90	44	3·06	2·34	0·72	1·05	0·857	0·027	...	Grey.
PHOSPHORUS.	4	24·4	0·094	12·67	47	3·28	2·15	1·13	1·00	0·014	..	0·090	Narrow white edge
	41	21·2	0·093	13·20	40·5	3·24	2·05	1·19	1·05	. .	..	0·406	Uniform open grey.
	42	25·0	0·118	15·30	43	3·19	2·19	1·00	1·03	..	..	0·810	Closer grain
	43	22·1	0·074	12·50	62	2·48	0·90	1·58	1·05		.	2·000	Whitish tinged grey
	7	23·8	0·132	10·10	43	3·02	2·10	0·92	1·62	0·040	0·015	0·093	Light grey
	44	26·1	0·128	14·90	37·5	3·03	2·14	0·89	1·62	.	..	0·400	Later grey.
	45	27·7	0·119		37	3·05	2·17*	0·88	1·40	..	.	0·620	,,
	46	27·2	0·123	15·56	40	3·01	2·14	0·87	1·58	.		0·755	,,
	47	24·4	0·090	7·68	48	2·77	1·63	1·14	1·40	...		1·225	.
	48	18·9	0·073	11·39	54	2·41	1·03	1·38	1·59	.		1·745	Mottled grey
	9	23·8	0·080	14·33	40·5	2·88	1·80	1·08	2·03	0·020	.	0·030	Light grey, open.
	49	26·3	0·121	15·10	40	2·83	1·78	1·05	2·05		..	0·512	Speckled grey.
	50	32·4	0·109	5·65	40·5	2·64	1·56	1·08	2·34		.	0·980	,, paler.
	51	24·1		12·10	43	2·66	1·39	1·27	2·00			1·100	.
	52	19·7	0·080	10·87	52·5	2·26	1·11	1·15	2·46			1·850	.
	53	16·6	0·050	11·10	58	2·25	0·92	1·33	2·08			2·246	
	54	20·4	0·055	7·93	62·5	2·42	1·33	1·09	2·00			2·880	Glazed appearance

* Broke in shoulder. Turned down to ½in. and retested, broke at 21·2 tons per square inch.

Reference to the figures given in Table I. shows the influence of small additions of sulphur on the mechanical and chemical properties. The author has already discussed most of the results given in this portion of the table in a paper entitled "Sulphur in Cast Iron," read before the British Foundrymen's Association (1911-12, p. 78), so that only brief reference to it is required here. The outstanding features may be summarised as follows:—

(1) The influence of sulphur on the condition of the carbon is dependent to a considerable extent on the percentage of silicon; with a low silicon content the addition of mer-

traces of sulphur is sufficient to throw the greater part of the carbon into the combined form in the conditions under which the bars were cast, while with a higher silicon content appreciable additions of sulphur may be made without any considerable change in the condition of the carbon. The hardness of the bars is largely a function of the combined carbon.

(2) The strength of the bars increases in a remarkable manner with the increase in sulphur content, especially in the case of the bars which are wholly grey. Bar 37, which

(3) Manganese in the proportions required to form MnS practically neutralises the normal influence of sulphur on the condition of the carbon, and in excess it tends to the elimination of sulphur owing to the separation of manganese sulphide from the fluid cast iron before solidification commences. The mixture made up for Bar 40 was equivalent to 1·2 per cent. manganese and 0·2 per cent. sulphur.

(4) There was no evidence in the experiments described to show that high sulphur content results in the formation of blowholes.

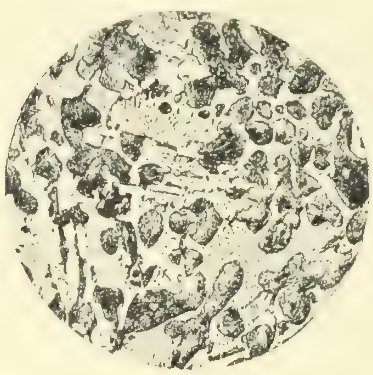


FIG. 1.
Bar 1. 0·42 per cent. silicon. Magnified 80 diameters.

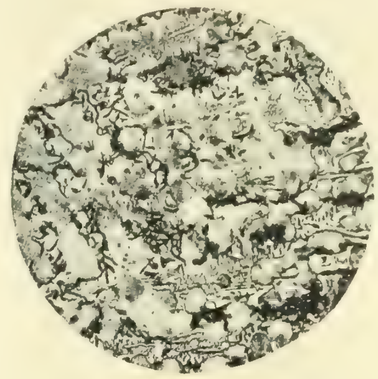


FIG. 2.
Bar 3. 0·80 per cent. silicon. Magnified 80 diameters.

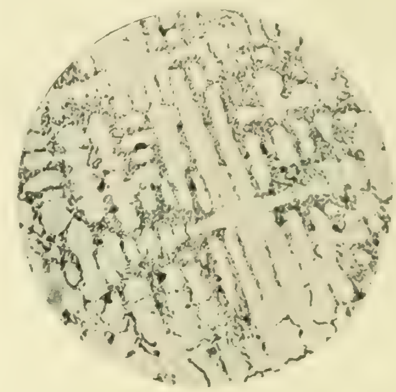


FIG. 3.
Bar 7. 1·62 per cent. silicon. Unetched. Magnified 80 diameters.

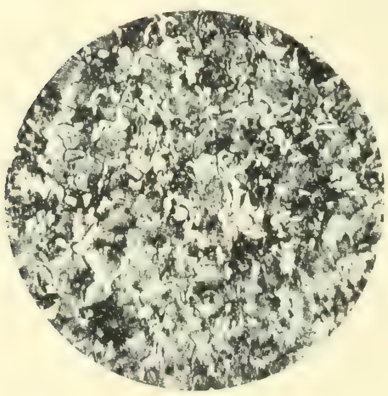


FIG. 4.
Bar 16. 1·52 per cent. silicon; 0·54 per cent. manganese. Magnified 80 diameters.

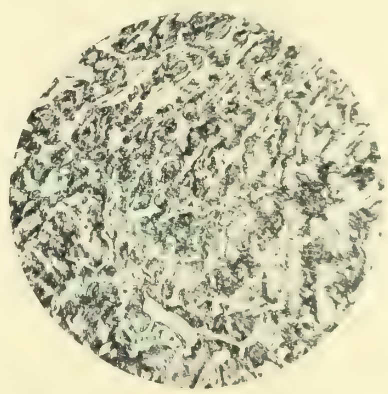


FIG. 5.
Bar 35. 1·55 per cent. silicon; 0·15 per cent. sulphur. Magnified 80 diameters.

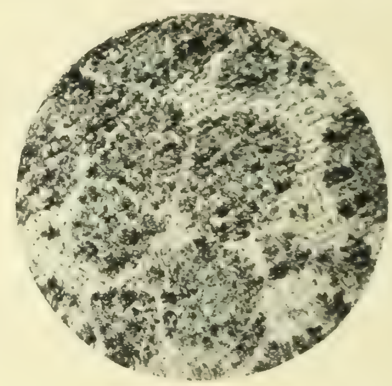


FIG. 6.
Bar 34. 1·69 per cent. silicon; 0·11 per cent. sulphur. Magnified 30 diameters.

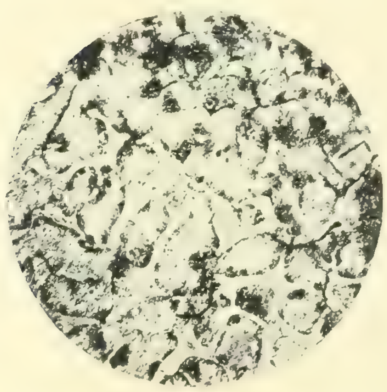


FIG. 7.
Bar 46. 1·58 per cent. silicon; 0·75 per cent. phosphorus. Magnified 130 diameters.

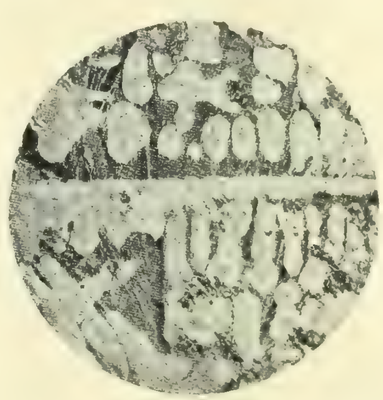


FIG. 8.
Bar 48. 1·59 per cent. silicon; 1·75 per cent. phosphorus. Heat tinted. Magnified 120 diameters.

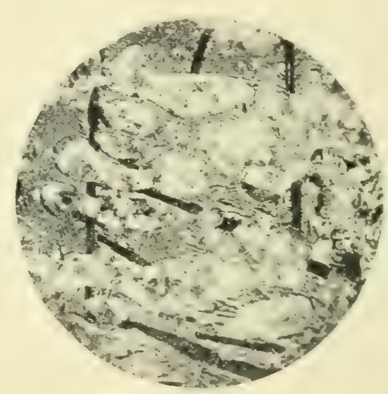


FIG. 9.
Bar 48. 1·59 per cent. silicon; 1·75 per cent. phosphorus. Heat tinted. Magnified 160 diameters.

has the high tensile strength of 21·2 tons per square inch, associated with high transverse strength and deflection, was too hard to be machined easily with ordinary tools, though it would be serviceable where small strong castings were required.

It is probable that the increased strength of the bars is due to the effect of sulphur in modifying the dendritic structure of the irons, and on the fineness of the graphite, more than to its effect on the condition of the carbon. Rough tests with a hammer showed no indication of brittleness due to sulphur.

The Influence of Phosphorus on Cast Iron Containing Silicon.—The physical and chemical relations of phosphorus and the iron carbon alloys were made the subject of a classical research by Dr. Stead, and the results were embodied in a paper presented to this Institute in 1900. Further interesting information relating to phosphorus in cast iron was given in Dr. Stead's address to the British Association, 1910. Wüst, too, has thoroughly investigated the influence of phosphorus on iron saturated with carbon, and has given complete information of the changes in these alloys in the absence of other impurities.

The influence of phosphorus on the condition of the carbon in siliceous irons is shown in Table I. Additions up to 1 per cent. have comparatively little effect, appearing slightly to diminish the percentage of combined carbon and to decrease the hardness, but larger quantities cause the retention of an increased percentage of carbon in the combined form. It is possible that two influences are at work. On the one hand, the tendency of phosphorus to retain iron carbide as the third constituent of a triple eutectic, and, on the other hand, the tendency to the formation of graphite owing to the metal remaining in the fluid or semi-fluid condition for a longer time by reason of the presence of phosphorus. With small percentages of phosphorus only the latter factor more than balances the tendency of phosphorus to retain the carbon in the combined form.

The chilling action of the sand in irons low in silicon is not nearly so marked in the presence of phosphorus. The addition of about 1 per cent. of phosphorus appears to strengthen cast iron, but the addition of 2 per cent. results in a hard, weak, brittle material possessing low deflection.

The Microstructure of the Cast Irons.—The microstructure in general bears out the change in the condition of the carbon, as shown by the analysis. Fig. 1 shows that the microstructure of Bar 1, 0·4 per cent. silicon, is identical with that of pure white iron containing about 3 per cent. of carbon. Further addition of silicon results in the partial breakdown of the iron carbide, as is illustrated by the microstructure of Bar 3, 0·8 per cent. silicon (Fig. 2). Fig. 3 shows that complete decomposition of all free iron carbide has taken place with the addition of 1·6 per cent. silicon. The specimen was not etched, and the photograph shows very clearly the marked dendritic form of the primary crystals, and also the replacement of the iron carbide-pearlite eutectic by one of graphite and pearlite. Whether this graphite-pearlite complex is a true eutectic is a matter for discussion. The pearlite (the result of the decomposition of austenite in the neighbourhood of 700° C.) is better developed in the irons that are mottled or white than in those that are grey. It may be repeated here that any diminution in the pronounced dendritic structure of the cast irons is accompanied by an increase in strength, and that the influence of sulphur in increasing the strength of cast iron is largely due to this action. Further addition of silicon within the limits of the experiments described is not accompanied by any change in the microstructure.

Manganese in small quantity (0·5 per cent.) added to grey irons results in the replacement of part of the pearlitic groundmass by ferrite (Fig. 4), thus bearing out remarks made in discussing the effect of manganese on the condition of the carbon and the hardness of the bars.

Fig. 5 illustrates the influence of a considerable addition of sulphur to an iron containing 1·55 per cent. silicon; in the absence of sulphur the iron carbide areas are absent. Fig. 6 is interesting, since it illustrates a structure under low power, which has been shown to be characteristic of cast irons possessing considerable strength. Further, it points to an interesting sequence in the solidification of the metal, grey areas consisting of pearlite and graphite being surrounded by a network of the iron carbide-pearlite eutectic, which solidifies last. The blobs of yellow-brown iron sulphide, FeS, in the grey irons of the series were found towards the boundaries of the primary crystals, while in the mottled and white irons the greater portion of the iron sulphide was observed in association with the iron carbide-pearlite eutectic.

The addition of phosphorus results, as is well known, in the formation of a eutectic, the nature of which varies according to the amount of other impurities present in the cast iron. Fig. 7, of Bar 46, 1·6 per cent. silicon, 0·75 per cent. phosphorus, shows the normal form of phosphide eutectic, together with flakes of graphite embedded in a groundmass of pearlite. There are apparently three stages in the solidification of such an iron: (1) The separation of primary austenite crystals, followed by (2) a separation of graphite, and afterwards by (3) the solidification of the eutectic.

Fig. 8 (Bar 48, 1·6 per cent. silicon, 1·95 per cent. phosphorus, heat tinted) shows a considerable change in the character of the eutectic, which now appears to consist of three constituents—iron carbide, tinted darkest; iron phosphide, slightly lighter; and pearlite, which make up a ternary eutectic. The rectilinear crystallisation of the iron carbide is well displayed in Fig. 9, a photograph of the same iron. It explains the brittleness of these cast irons, since these thin plates of hard brittle material form lines of weakness along which fracture easily takes place.

Pyrometric Results.—An investigation was made of the influence of the metalloids on the temperature of pearlite formation, and results were obtained in accordance with those that have already been published, namely, that silicon raises the temperature of pearlite formation by some 25° C. for each per cent. added, while the addition of 1 per cent. of manganese depresses that point by about the same number of degrees.

Complete cooling curves of a number of phosphoric irons were taken; 450 grammes each of Bars 9, 49, 50, 51, 53, 54, containing about 2 per cent. of silicon, and up to 2·8 per cent. of phosphorus, were melted in a gas-injector furnace and readings taken during cooling on a thermocouple potentiometer. The composition of the buttons obtained were as follows:—

	A.*	B.	C.	D.	E.*	F.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Total carbon	2·71	2·82	2·60	2·68	2·20	2·38
Graphitic carbon	2·54	2·08	1·55	1·60	1·50	1·31
Combined carbon	0·17	0·74	1·05	1·08	0·70	1·07
Silicon	2·01	2·09	2·17	1·81	1·83	1·85
Phosphorus..................	0·09	0·53	1·01	1·23	2·16	2·90

* Reheated to about 910° C. and cooled slowly.

The curves drawn in Fig. 10 show a number of interesting arrest points. The temperature of initial solidification

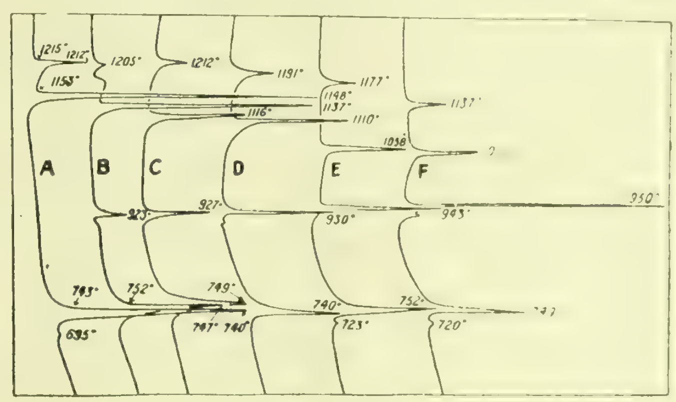


Fig. 10.

is lowered, at first slightly, then more rapidly, with over 2 per cent. of phosphorus. The same statement holds good for the second arrest point, except that the effect is more marked; the intensity of this arrest diminishes with increase in phosphorus. The third arrest point in those melts containing phosphorus is due to the solidification at about 930° C. of a phosphide eutectic; the intensity of this arrest increases with the increase in phosphorus content, which also raises the actual temperature at which solidification takes place. The fourth arrest point, due to the formation of pearlite, does not appear to be influenced by the addition of phosphorus. In melts E and F a slight arrest was observed at 720° C. which may be due, as suggested by Dr. Stead, to the formation of pearlite from the austenite of the ternary eutectic. The assistance of the microscope is required in the interpretation of these various arrest points on the cooling curves, and the remarks made in discussing the microstructure of the bars will be sufficient to explain the arrests.

Finally, with regard to the formation of graphite in cast irons, there was strong evidence in many cases of the preliminary separation of carbide of iron, followed by its decomposition with the liberation of graphite. In a section, part of which is shown in Fig. 2, the complete sequence could easily be followed.

Undecomposed areas of eutectic were associated with

others in which part of the iron carbide had just decomposed before complete solidification took place; mere spots or very small flakes of graphite had formed, but nearer the centre of the bar, which remained fluid rather longer, long flakes had formed by the linking up of these spots or smaller flakes.

Summary.—Silicon decreases the strength and hardness of cast iron owing to its effect in promoting the decomposition of iron carbide.

Manganese to the extent of 0·5 per cent. results in a considerable softening of siliceous grey irons, owing to its effect on the condition of the carbon. The strength is increased by the addition of manganese.

The influence of sulphur is largely determined by the percentage of silicon present. Carefully controlled, it should be of considerable value to the ironfounder in mixing his irons for any particular purpose.

In the absence of manganese, and in the presence of about 2 per cent. of silicon, very strong grey cast irons may be obtained if the percentage of sulphur be judiciously raised.

Phosphorus to the extent of about 1 per cent. is useful, since it confers fluidity upon cast iron, slightly increases the strength, and also slightly diminishes the hardness of the metal. A higher percentage results, however, in a hard brittle material.

PULLEN'S FUEL CALORIMETER.

THE calorimeter shown in the accompanying sectional view, the invention of Mr. W. W. F. Pullen, 24, Heaton Moor Road, near Stockport, has been designed to provide a simple and efficient instrument for determining the heating or calorific value of a fuel. The crucible C which contains the fuel to be burnt is constructed of a conical or V shape, so that if the fuel burns faster on one side than another, the unburnt fuel will fall towards the bottom of the crucible, where the stream of oxygen from the tube M will play upon it, and compel the combustible part of the sample to burn. The conical shape of the crucible also compels the jet of oxygen to scour more thoroughly the bottom of the crucible, whatever be the position of the tube M relative to the axis of the crucible, and thus to carry sufficient oxygen to the unburnt fuel on all occasions. The tube M is cranked or formed with a portion set eccentrically with the axis of the crucible, so that by turning the tube about the axis of its upper part, its lower end will sweep across the top of the crucible, by which means the jet of oxygen may be directed upon different parts of the sample of fuel. To permit of the maximum effect of the cranked tube, its axis is arranged slightly eccentric with the top cover E of the combustion chamber.

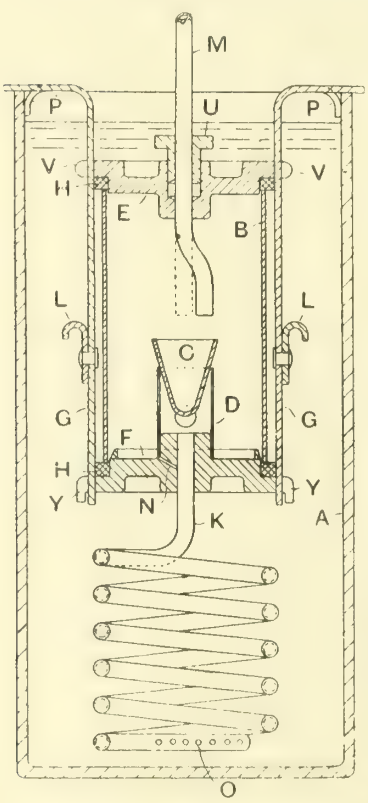
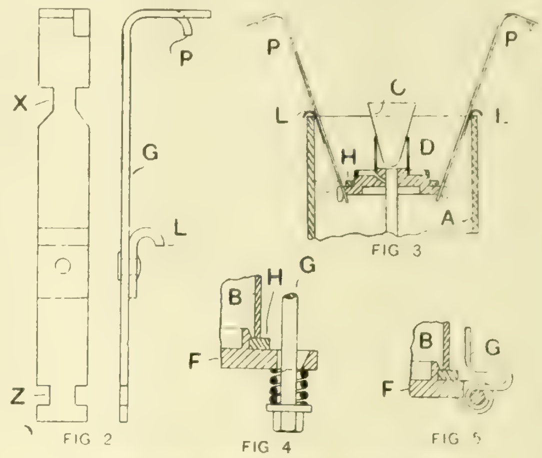


FIG. 1. PULLEN'S FUEL CALORIMETER.

The crucible C is supported in the end of a short perforated tube D. The perforations permit the heated products of combustion to pass into the coil K, which they traverse before emerging through the orifices O into the water at the bottom of the calorimeter. The part of the coil containing the orifices O is so shaped that the products of combustion will leave the coil on one side only of the calorimeter and rise through the water approximately midway, radially, between the combustion chamber and the outer vessel, the object being to enable the gases to rise as freely as possible, and with little resistance from the combustion chamber or the outer vessel. The rapidly rising bubbles on one side only of the calorimeter carry with them the water in their immediate neighbourhood, and thus produce a somewhat rapid circulation of the water, which will not only permit of the more thorough extraction of the heat from the outer surfaces of the combustion chamber and the cooling coil K, but will thoroughly mix and churn the water in the calorimeter, and thus produce a uniform temperature throughout the calorimeter. The coil K ensures that the greater part of the heat



DETAILS OF PULLEN'S FUEL CALORIMETER.

of combustion is communicated to the water before the gases reach the water.

The combustion chamber is formed of a glass vessel B, closed at its ends by covers E and F. The ends of the glass vessel butt against rubber rings H, the whole being held together by clips or tie pieces G. The latter are shown in greater detail in Fig. 2. The notches Z are threaded over the corresponding horns of the lower cover of the combustion chamber Y (Fig. 1), and the notches X (Fig. 2) are threaded over the horns V of the upper cover (Fig. 1). The horns Y on the lower cover in Fig. 1 are so shaped that the clips G cannot be disconnected therefrom without first being turned in a vertical plane through a considerable angle. The horns V on the top cover are made with their upper surfaces inclined, so as to produce a wedging action which draws the top and bottom covers towards each other as the clips are forced into position, thus producing water-tight joints at the ends of the glass chamber B. The clips G may be attached to the lower cover by pins, as shown in Fig. 5. To enable the same clips to be used with slightly different lengths of glass B or with the ends slightly out of parallel, the clips may be constructed with adjustable or elastic ends, as shown in Fig. 4, the helical spring permitting of considerable automatic adjustment of the length of the clips to suit the glass vessel B. Each of the clips G is constructed with a hook or projection L for the purpose of supporting the lower cover of the combustion chamber during the assembling or disassembling of its parts, or during the process of conducting part of the experiment, as shown in Fig. 3. In this position, the crucible C is arranged to be above the water. The combustion chamber is maintained approximately in a central position in the outer vessel A by the portions P of the clips. The oxygen tube M is capable of longitudinal adjustment, and water is prevented from gaining access to the combustion chamber through the top cover by the gland U. To enable any water to escape from the combustion chamber, the projection or boss that holds the perforated tube D is pierced with a small hole N, leading down into the coil K.

Iron and Steel Institute Awards.—The Iron and Steel Institute have awarded the Carnegie Gold Medal for 1912 to Dr. J. Newton Friend, for his research work on the corrosion of iron and steel. The Carnegie £100 Research Scholarship awards for this year are as follows: Herr Aufelstedt (Dresden); M. Louis Baraducmuller (Paris); Herr Hans Rudeloff (Gross-Lichterfelde W.); Mr. Neal Brodie (Newcastle); Mr. A. Hirsch (New York); and Mr. W. H. Paterson (Birkenhead).

THE DESIGN OF VOLUTE CHAMBERS AND OF GUIDE-PASSAGES FOR CENTRIFUGAL PUMPS.*

BY PROF. A. H. GIBSON, D.SC.

OF all the losses in the centrifugal pump, that due to the impossibility of converting all the kinetic energy of the water leaving the impeller into pressure energy is the most important. In a modern pump this kinetic energy usually amounts to between 30 and 50 per cent. of the total energy at discharge from the impeller, and the efficiency of the pump

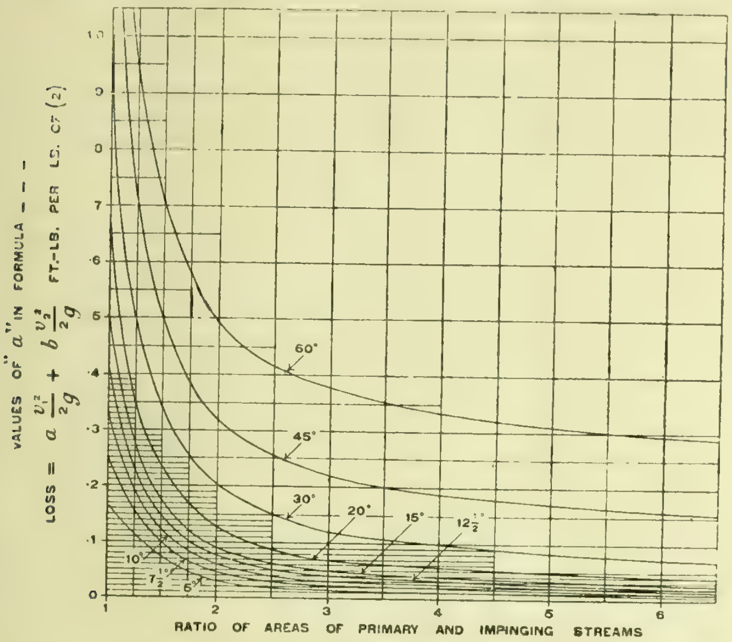


FIG. 1.

depends very largely on the efficiency of its conversion into pressure energy.

Of the devices adopted with this end in view, the ring of guide-vanes surrounding the impeller, and forming divergent passages in which the velocity is gradually reduced, is the most efficient under favourable conditions, and may enable some 75 per cent. of the energy to be converted. Since the efficiency of such a system depends largely on the suitability of the vane angles, unless these are so designed as to receive, without shock, the streams leaving the impeller, their value is considerably reduced. As with fixed guide-vanes this angle can only be adapted to one particular speed and delivery, any deviation from the normal working conditions reduces their efficiency. Furthermore, where, as is often the case, there is a possibility of floating débris being drawn into the pump, the jamming of this between the impeller and guide-vanes may distort the tips of the latter, with serious results as regards the working of the installation.

For this, among other reasons, modern pump design appears to be tending in the direction of the simpler type of pump with a modified vortex chamber or a simple volute surrounding the impeller, but without guide-vanes. During the last few years many such pumps have been built both in the United States and, to a smaller extent, in this country, for comparatively high lifts. The efficiency of such a pump depends in a high degree on that of its volute considered as an energy-conversion device, and the latter efficiency must obviously depend on the proportions of the volute. Apart from friction, the loss in a volute chamber is due to eddy formation accompanying the impact of the streams leaving the impeller on the body of water flowing around the volute. It is evident that some definite proportions for the latter chamber will reduce this loss to a minimum, and furthermore, that a rational design can only be based on a knowledge of the magnitudes of such losses and of their dependence on the velocities and angles of impact, and on the cross-sectional areas of the streams involved. The lack of such experimental data is doubtless responsible for the great divergence of opinion as to the best proportions to be adopted, which, as shown by a comparison of modern pumps by reputable makers, exists among those responsible for their design.

* Paper presented to the Institution of Mechanical Engineers.

Recent experiments at University College, Dundee, on the losses accompanying the impact of confined jets have, however, furnished data which appear to enable a rational basis of design to be formulated. This is developed in the present paper, but it may be advisable first, for purposes of comparison, to outline the assumptions on which present day design is often based. In this discussion the following symbols will be used :—

u_2 represents the velocity of the impeller at its outer periphery.
w_2 represents the tangential component of the velocity of the water leaving the impeller.
f_2 represents the radial component of the velocity of the water leaving the impeller.
v_2 represents the absolute velocity of the water leaving the impeller.
v_1 represents the velocity of flow in the volute.
θ represents the angle which the discharging streams make with the mean direction of flow in the volute.

Owing to the divergence of the sides of the volute, θ will probably be slightly less than the angle between the direction of the discharging streams and the tangent at the point of discharge. The difference can, however, only be small and, being unknown, will be neglected.

When a stream of water at velocity v_2 impinges at an angle θ on a second stream moving with velocity v_1, it has been usual to assume that the loss of energy per pound of the impinging stream is given by

$$\frac{(v_2 \sin \theta)^2}{2g} + \frac{(v_2 \cos \theta - v_1)^2}{2g} \text{ ft.-lb.} \quad . \quad . \quad . \quad . \quad (1)$$

or, as applied to the case of the pump, by

$$\frac{f_2^2 + (w_2 - v_1)^2}{2g} \text{ ft.-lb.} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The first term represents the kinetic energy in virtue of the normal component of the velocity of impact, which is assumed to be entirely lost, and the second term represents the loss of the energy possessed in virtue of the tangential component of the velocity.

Here v_2 and θ depend on the design of the impeller and on its speed and discharge, but are independent of the form of the volute, which, however, determines v_1. As, if there

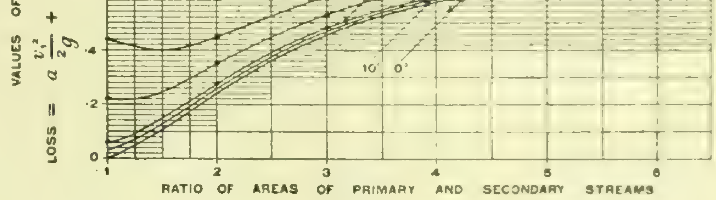


FIG. 2.

were no impact losses, the gain of pressure energy in the volute would be $\frac{v_2^2 - v_1^2}{2g}$ or sensibly $\frac{(v_2 \cos \theta)^2 - v_1^2}{2g}$ ft.-lb. per lb., the total gain of energy, on this assumption, is approximately equal to

$$\frac{(v_2 \cos \theta)^2 - v_1^2 - (v_2 \cos \theta - v_1)^2}{2g} \text{ ft.-lb. per lb.} \quad . \quad . \quad (3)$$

This is a maximum, and equal to

$$0{\cdot}5 \frac{(v_2 \cos \theta)^2}{2g} \text{ or } 0{\cdot}5 \frac{w_2^2}{2g} \text{ when } v_1 = 0{\cdot}5\, w_2.$$

In modern pumps θ is usually between 6° and 12°, so that $\cos \theta$ is approximately unity, and this makes v_1 approximately

one-half v_2. On these assumptions the most efficient volute would make v_1 equal to $\frac{v_2}{2}$ and would then have an efficiency of practically 50 per cent. Since this discussion neglects friction losses, a more efficient design would have a somewhat smaller value of v_1, and in practice v_1 usually lies between $0{\cdot}37\ v_2$ and $0{\cdot}45\ v_2$.

In such a chamber the area usually increases uniformly from E to D, Fig. 5, its value being calculated so as to give

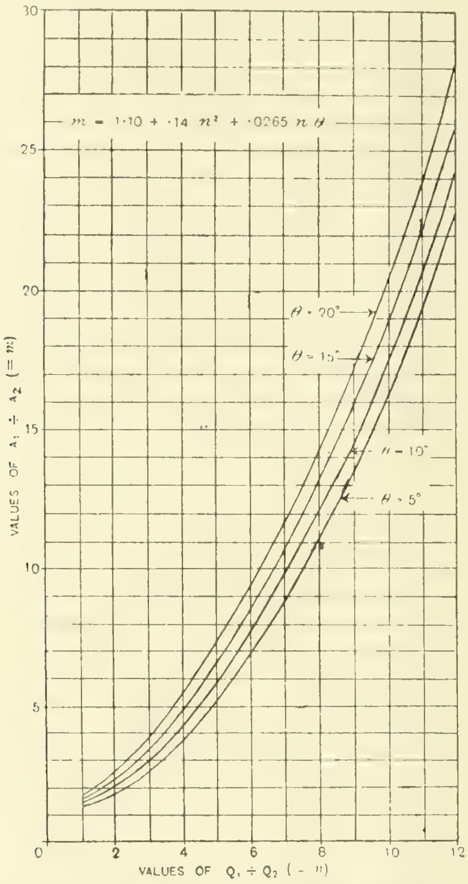


FIG. 3.—VALUES OF "m" GIVING MINIMUM LOSS.

this velocity of flow at each point under normal working conditions. An examination of modern pumps of this type shows that instead of some 50 per cent. of the kinetic energy of discharge being converted into pressure energy in the volute, only between 10 per cent. and 30 per cent. is actually so converted.

The assumptions on which the foregoing analysis is based cannot, however, be justified either theoretically or experimentally, and a more rational basis of design will now be outlined.

Experimental Determination of Impact Losses.—Recent experiments* on the loss at impact of impinging streams, only one of which is deviated by the impact, show that if

v_1 is the velocity of the primary (undeviated) stream,
A_1 is the area of the primary (undeviated) stream,
v_2 is the velocity of the impinging (deviated) stream,
A_2 is the area of the impinging (deviated) stream,
θ is the angle of impact,

the loss is equal to

$$a\frac{v_1^2}{2g}+b\frac{v_2^2}{2g}\text{ ft.-lb. per lb. of the impinging stream} \qquad (4)$$

The values of a and b in this formula depend not only on θ, but on the ratio of A_1 to A_2. Calling this ratio m, they are given with a close degree of accuracy by the relationships

$$a=\frac{0{\cdot}0052}{m}\,\theta^{1{\cdot}28}\text{ where }\theta\text{ is in degrees,}$$

$$b=\left(\frac{m-1}{m}\right)^2+\frac{0{\cdot}00046}{m}\,\theta^{1{\cdot}8},$$

so long as m is greater than 2.

* By the author, Trans., Royal Society of Edinburgh, 1913, Vol. XLVIII., Part 4, page 799.

The values of a and b for values of m between 1 and 6, and for various values of θ, are given graphically in the curves of Figs. 1 and 2.

If Q_1 and Q_2 are the volumes, in cubic feet per second, conveyed by the two streams, and if $Q_1 = nQ_2$, the formula

$$\text{loss}=a\frac{v_1^2}{2g}+b\frac{v_2^2}{2g}\text{ may be written—}$$

$$\text{loss}=\left\{a\left(\frac{n}{m}\right)^2+b\right\}\frac{v_2^2}{2g}\text{ ft.-lb. per lb. of steam (2)} \qquad (5)$$

The error involved by a use of the old formula—

$$\text{loss}=\frac{(v_2\sin\theta)^2+(v_2\cos\theta-v_1)^2}{2g}\text{ ft.-lb.}$$

depends largely on the values of v_1, v_2, θ, and m. The values of the losses calculated by this formula and expressed as a fraction of $\frac{v_2^2}{2g}$ are shown in Table I., against those experimentally obtained. These figures sufficiently emphasize the inaccuracy of the formula.

TABLE I.

	Values of θ.					
——	10° Loss.		15° Loss.		30° Loss.	
	Actual.	Calculated.	Actual.	Calculated.	Actual.	Calculated.
$m=2$, $v_1=v_2$	0·322	0·030	0·37	0·07	0·55	0·27
$m=2$, $v_1=0{\cdot}5v_2$	0·277	0·265	0·30	0·28	0·40	0·38
$m=2$, $v_1=0{\cdot}25v_2$	0·266	0·570	0·28	0·58	0·36	0·63
$m=4$, $v_1=v_2$	0·605	0·030	0·62	0·07	0·72	0·27
$m=4$, $v_1=0{\cdot}5v_2$	0·582	0·265	0·59	0·28	0·64	0·38
$m=4$, $v_1=0{\cdot}25v_2$	0·577	0·570	0·58	0·58	0·63	0·63
$m=6$, $v_1=v_2$	0·721	0·030	0·74	0·07	0·80	0·27
$m=6$, $v_1=0{\cdot}5v_2$	0·705	0·265	0·72	0·28	0·75	0·38
$m=6$, $v_1=0{\cdot}25v_2$	0·701	0·570	0·71	0·58	0·73	0·63

Application to the Design of Volute Chambers.—On the assumption that the state of affairs during the impact of each of the streams leaving the impeller of a pump is analogous to that in a single stream impinging under the same conditions as to direction and velocity, the foregoing results may be used to determine the necessary areas of the volute chamber for maximum conversion of energy.

If v_d be the velocity of flow along the discharge pipe of a pump, if there were no losses other than those already con-

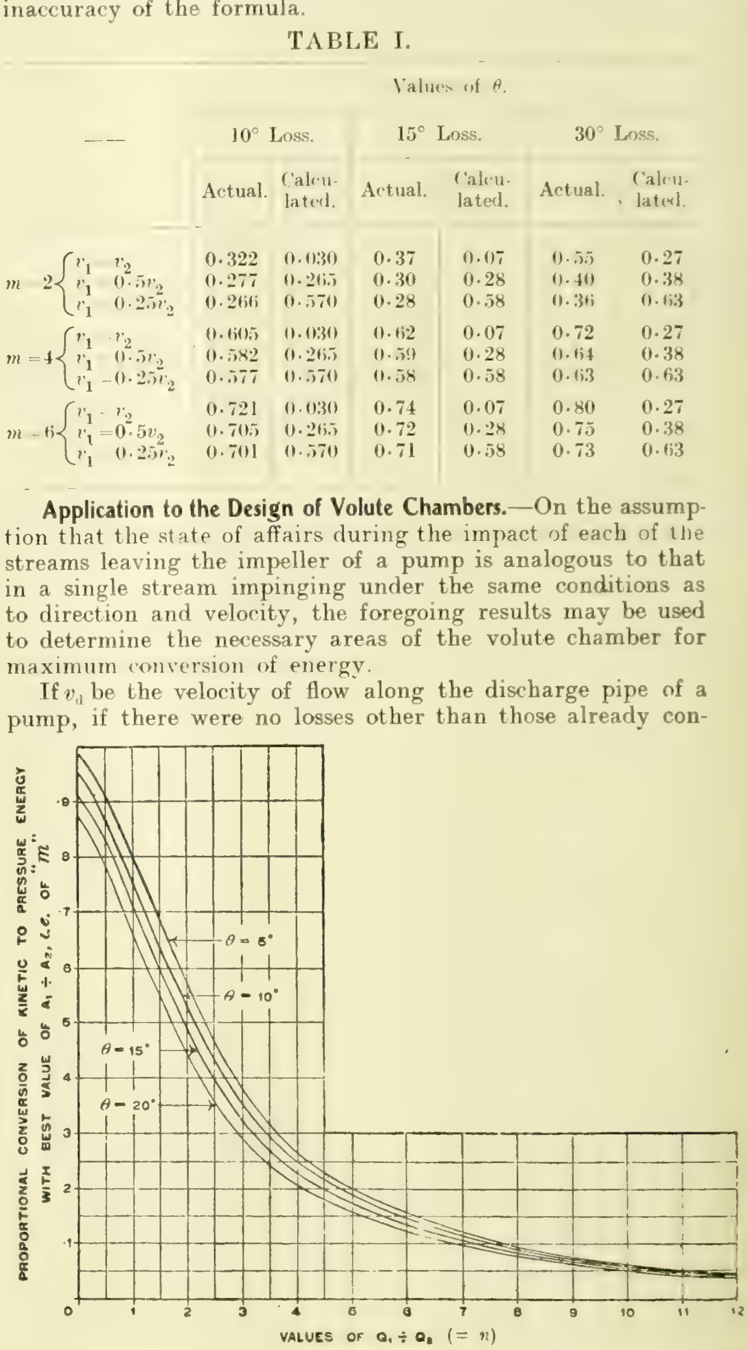


FIG. 4.

sidered, the increase of pressure energy in a stream discharging into the volute at a point where the volute velocity is v_1 would be given by

$$\frac{1}{2g}\left\{v_2^2-v_d^2-(a\,v_1^2+b\,v_2^2)\right\}\text{ft.-lb. per lb.}$$

Actually, the reduction of velocity from v_1 to v_d is accompanied by a further loss of energy which is proportional to

$(v_1 - v_d)^2$. Experiments on flow in diverging passages* show that if the sides diverge at an angle of 6° in a circular pipe) the loss of head, including friction, is about $0{\cdot}13\,\frac{(v_1 - v_d)^2}{2g}$. For values of the angle either greater or less than 6° the loss is greater, and for such angles of divergence as are usual in the volute chambers of pumps, where these are of circular or approximately circular section, may be taken as $0{\cdot}15\,\frac{(v_1 - v_d)^2}{2g}$ without sensible error. The total increase of pressure energy after leaving the impeller will then be given by

$$\frac{1}{2g}\left\{v_2^2 - v_d^2 - 0{\cdot}15\,(v_1 - v_d)^2 - (a\,v_1^2 + b\,v_2^2)\right\}$$

$$= \frac{1}{2g}\left\{v_2^2\,(1 - b) - (0{\cdot}15 + a)\,v_1^2 - v_d\,(1{\cdot}15\,v_d - 0{\cdot}30\,v_1)\right\}$$

ft.-lb. per pound of discharge from the impeller.

If $v_1 = 3{\cdot}85\,v_d$, this simplifies to

$$\frac{v_2^2}{2g}\left[(1 - b) - \left(\frac{n}{m}\right)^2\left\{0{\cdot}15 + a\right\}\right] \text{ ft.-lb. per lb.} \quad . \quad . \quad (6)$$

where m is the ratio of the cross-sectional area of the volute at the point under consideration, to the area of the stream leaving the impeller.

This ratio of v_1 to v_d is in close agreement with practice, and as any probable deviation from it has a comparatively small effect in modifying the result, the simple formula (6) will be taken as applying throughout the discussion.

If the ratio $Q_1 \div Q_2$ $(= n)$ be known, the known values of a and b enable the value of m for maximum gain of pressure to be calculated by successive approximations. For example, if $\theta = 10°$, and $Q_1 = 2\,Q_2$ $(n = 2)$, a reference to Figs. 1 and 2 shows that:—

if $m = 1{\cdot}5$, $a = 0{\cdot}122$; $b = 0{\cdot}122$ ∴ $\left\{\begin{matrix}\text{gain of}\\ \text{pressure}\end{matrix}\right\} = (0{\cdot}878 - 0{\cdot}484)\frac{v_2^2}{2g} = 0{\cdot}394\frac{v_2^2}{2g}$

,, $m = 1{\cdot}75$, $a = 0{\cdot}085$; $b = 0{\cdot}190$,, $= (0{\cdot}810 - 0{\cdot}307)\frac{v_2^2}{2g} = 0{\cdot}503\frac{v_2^2}{2g}$

,, $m = 2{\cdot}0$, $a = 0{\cdot}060$; $b = 0{\cdot}255$,, $= (0{\cdot}745 - 0{\cdot}210)\frac{v_2^2}{2g} = 0{\cdot}535\frac{v_2^2}{2g}$

,, $m = 2{\cdot}5$, $a = 0{\cdot}040$; $b = 0{\cdot}375$,, $= (0{\cdot}625 - 0{\cdot}115)\frac{v_2^2}{2g} = 0{\cdot}510\frac{v_2^2}{2g}$

On plotting against values of m, it appears that the maximum gain is attained when $m = 2{\cdot}1$ and equals $0{\cdot}536\,\frac{v_2^2}{2g}$ feet.

To facilitate the solution of practical problems the range of values of θ from 0° to 20° and of m from 1 to 28 have been examined in this way. As a result it appears that the value of m for maximum gain of pressure, or for minimum loss by shock and by rejection of kinetic energy, is given with a close degree of accuracy by the relationship

$$m = 1{\cdot}10 + 0{\cdot}14\,n^2 + 0{\cdot}0265\,n\,\theta \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

where $n = Q_1 \div Q_2$, and θ is in degrees.

The best values of m for different values of n and of θ are shown graphically in Fig. 3, while Fig. 4 (the data for which have been calculated as above) shows what fraction of the kinetic energy of discharge is converted into pressure energy with these best values of m.

In the volute chamber, let θ be the angle of impact of each of the discharging streams, Fig. 5; N the number of vanes or passages in the impeller; γ their discharge angle; r the radius, and b the breadth of the impeller at its outer periphery.

Let Q_2 be the volume discharged from each passage per second. Then at a point distant x (measured along the periphery of the impeller) from E, Fig. 5, the volume of flow in the volute, *i.e.*, Q_1, is equal to $\frac{NQ_2x}{2\pi r}$

$$\therefore \frac{Q_1}{Q_2} = \frac{Nx}{2\pi r} = n \text{ of the foregoing formula.}$$

The effective area of each impinging stream, normal to its direction of flow, $= \frac{2\pi rb}{N}\sin\theta$ (neglecting the space occupied by the vanes), and the value "y" of the area of the volute at this point for minimum loss is given by:—

$y =$ (effective discharge area of each passage) $\times\ m$. (8)

where m is given for any value of n, and of θ either by formula (7) or by the curves of Fig. 3.

* Royal Society of Edinburgh, 1911, Vol. XLVIII., page 97.

For example, let $r = 8$in.; $b = 1{\cdot}5$in.; No. of vanes $N = 10$; $\theta = 10°$.

Then

Sin θ = 0·1736, and the effective area of each stream

$$= \frac{2\pi \times 8 \times 1{\cdot}5 \times 0{\cdot}1736}{10} = 1{\cdot}31 \text{ sq. in.}$$

Therefore where:—

sq. in.

$x = \frac{2\pi r}{N}$ *i.e.* $\frac{Q_1}{Q_2} = 1$, $m = 1{\cdot}4$ (Fig. 3) and $y = 1{\cdot}4 \times 1{\cdot}31 = 1{\cdot}84$

$x = \frac{4\pi r}{N}$,, $\frac{Q_1}{Q_2} = 2$, $m = 2{\cdot}1$,, $y = 2{\cdot}1 \times 1{\cdot}31 = 2{\cdot}75$

$x = \frac{8\pi r}{N}$,, $\frac{Q^1}{Q_2} = 4$, $m = 4{\cdot}3$,, $y = 4{\cdot}3 \times 1{\cdot}31 = 5{\cdot}62$

$x = \frac{12\pi r}{N}$,, $\frac{Q_1}{Q_2} = 6$, $m = 7{\cdot}8$,, $y = 7{\cdot}8 \times 1{\cdot}31 = 10{\cdot}2$

$x = \frac{16\pi r}{N}$,, $\frac{Q_1}{Q_1} = 8$, $m = 12{\cdot}1$,, $y = 12{\cdot}1 \times 1{\cdot}31 = 15{\cdot}8$

$x = \frac{20\pi r}{N}$,, $\frac{Q_1}{Q_2} = 10$ (at B), $m = 17{\cdot}5$,, $y = 17{\cdot}5 \times 1{\cdot}31 = 22{\cdot}9$

The conversion into pressure-energy per pound of the impinging stream at each of these points is given by the corresponding ordinates of the curve marked 10° in Fig. 4,

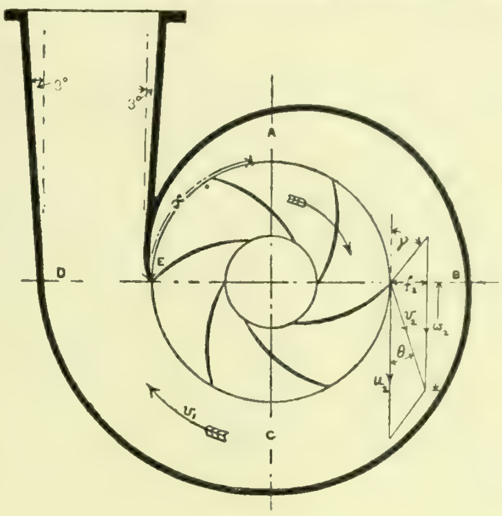


FIG. 5.

and the mean height of this curve between the ordinates $\frac{Q_1}{Q_2} = 0$, and 10 gives the mean increase in pressure outside the impeller, expressed as a fraction of $\frac{v_2^2}{2g}$. In this case it amounts to $0{\cdot}30\,\frac{v_2^2}{2g}$, indicating that a volute for this pump, however well designed, cannot utilise more than 30 per cent. of the kinetic energy of discharge.

An examination of Fig. 4 shows that the loss increases rapidly as the ratio of $Q_1 \div Q_2$ in the volute increases, that is, towards the discharge end of the volute, and as the maximum value of this ratio is the same as the number of vanes in the impeller, it also indicates that an increase in the number of vanes, even with a volute designed to suit this number, increases the shock loss. This point is brought out by Table II., which shows the increase in pressure, in terms of $\frac{v_2^2}{2g}$, with each of a series of volutes of best form, designed respectively to take the discharge from 1, 2, 3, 4, 6, 8, 10, or 12 vanes, and for different values of θ.

From this it appears that in a pump of this type the smaller the number of vanes, the more efficient is the corresponding volute, and other things being equal, also the pump. This statement is, however, to be qualified by the fact that too few vanes give insufficient guidance to the water, and increase the tendency to the formation of circulatory currents behind the discharging edge of each vane.

Experimental evidence on this point is not conclusive, since from what has already been said it will be evident that,

for an impeller with a given number of vanes to give its best results, the volute chamber must be designed to suit this number of vanes, whereas such comparative tests of impellers as are available have been carried out with a common volute, and are not therefore of great value. Still the curves of Fig. 6, which are prepared from the results of recent tests at the University of Wisconsin on a pump having an impeller 8·81in.

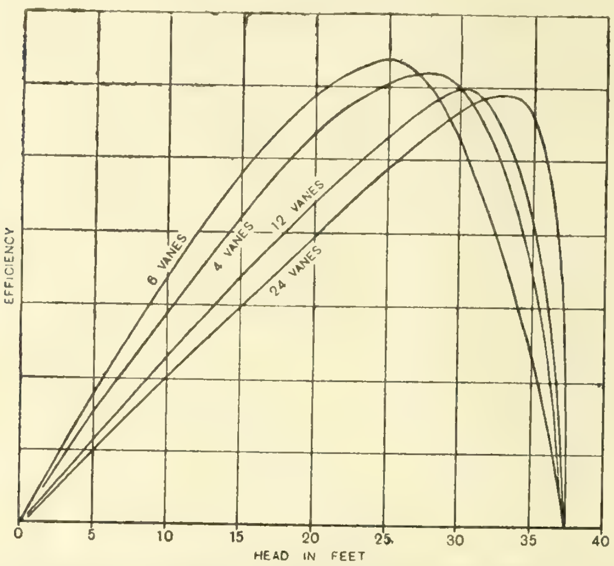


FIG. 6.—COMPARATIVE RESULTS OF IMPELLERS WITH DIFFERENT NUMBER OF VANES.

diam. × 1·125in. wide,* with vanes having radial tips, and so formed as to give a constant area of waterway, indicate that there is a good deal in the contention.

TABLE II.—*Proportion of Kinetic Energy of Discharge which may be converted into Pressure Energy with a Volute of Best Form.*

θ	Number of Vanes.							
	1	2	3	4	6	8	10	12
5°	0·90	0·79	0·68	0·59	0·46	0·38	0·32	0·28
7½°	0·88	0·77	0·66	0·57	0·45	0·37	0·31	0·27
10°	0·86	0·75	0·64	0·56	0·44	0·36	0·30	0·26
15°	0·82	0·71	0·61	0·53	0·41	0·34	0·28	0·24
20°	0·77	0·66	0·56	0·49	0·37	0·31	0·26	0·21

The figures of Table II. also indicate to what extent a reduction in the value of θ reduces the volute losses. In a given pump θ may be reduced by increasing the vane angle γ, but only at the expense of an increase in v_2, and theory shows, as is confirmed in practice, that little is to be gained by increasing γ beyond about 30°.

(To be continued.)

Railway Wonders of the World. — We have received from Messrs. Cassell & Co., La Belle Sauvage, Ludgate Hill, E.C., Part I. of a new publication entitled "Railway Wonders of the World." The work, which is to be completed in 24 fortnightly parts of 7d. each, gives a popular and well-illustrated description of some of the more important engineering triumphs associated with railway construction in various parts of the world. The photo views with which it is illustrated are of special merit and enable the general reader, without going into mechanical details, to realise the stupendous magnitude of some of the constructional tasks associated with the penetration of the locomotive in out-of-the-way corners of the world. Even to the engineer familiar with the mechanical details of railway and locomotive construction, the work will appeal as a striking illustration of the triumphs of his profession over natural obstacles, and for this reason we have pleasure in commending it to the notice of our readers.

* Bulletin, University of Wisconsin, 1907, No. 173, page 529.

SURFACE COMBUSTION.*

BY PROF. WILLIAM A. BONE, D.SC., PH.D., F.R.S.

(*Concluded from page* 519.)

Surface Combustion as Applied to Steam Raising. — I now come to an important application of the new process to the raising of steam in multitubular boilers; not that the application of surface combustion is limited to boilers of multitubular type, but because our investigations have so far been principally made with these. It is well known that the gas-firing of steam boilers has not been very successful from the point of view of thermal efficiency or of rate of evaporation. In this country the gases available for steam-raising purposes on a large scale are principally (1) blastfurnace gas, of which in S. Durham and Cleveland there is always a large surplus available; (2) the surplus gas obtainable during the manufacture of coke in by-product ovens—which in these parts is a growing quantity; and (3) producer gas of various compositions, but more particularly that manufactured under ammonia recovery conditions. In the United States, and some other oil-producing countries, natural gas of high calorific power is also available. All these gases have been found to be amenable to the system I am about to describe.

It has been estimated by a prominent British blastfurnace engineer that the thermal efficiency of the best type of water tube boiler, fired by blastfurnace gas, does not exceed about 55 per cent., and in the case of boilers fired by coke oven gas the average thermal efficiency probably does not much exceed 65 to 70 per cent. But on applying the principle of surface combustion to the gas firing of multitubular boilers, we have been able to obtain results with coal-gas corresponding to the transmission of nearly 95 per cent. of the net calorific value of the gas to the water in the boiler. I will now endeavour to explain the construction and performance of this new type of gas-fired boiler:—

The diagram (Fig. 6) represents an ordinary multitubular boiler of cylindrical section. It is traversed horizontally by a series of steel tubes, each 3ft. only in length and 3in. in internal diameter. These tubes are packed throughout their whole length with fragments of a suitable refractory material, meshed to a proper size. Into the front end of the tube, where the gaseous mixture is introduced, is fitted a fireclay plug, through which is bored a circular hole of about ¾in. diam. This plug serves a double purpose of keeping the front end of the boiler cool and of providing a suitable aperture through which the gaseous mixture may be introduced at a speed very much higher than the speed of back-firing.

Attached to the front plate of the boiler is a mixing chamber of special design (not shown in detail on the diagram). The mixture fed into the boiler tubes from this chamber consists of the combustible gas with a proportion of air very slightly in excess of that required for complete combustion. The mixture is injected or drawn in (either by pressure or by suction) through the orifice in this fireclay plug into the incandescent material in the tubes. The combustion of the mixture in contact with the incandescent material is completed before it has traversed a length of about 6in. from the point of entry to the tube. The result is that the core of the material at this part of the tube is maintained at a high temperature, although the *loci* of actual contact between the hot material and the walls of the tube are so rapidly cooled by the transmission of heat to the water in the boiler that they never attain a temperature anything even approaching red heat.

The combustion having been completed, the remainder of the material acts as a baffle toward the burnt gases as they traverse the tubes at a high velocity, causing them to impinge repeatedly on the walls of the tubes. The usual rate at which the gaseous mixture is fed into the boiler corresponds to an hourly consumption of about 100 cub. ft. of coal-gas plus six times its volume of air for every tube of the boiler, or an equivalent volume—*i.e.*, equivalent as regards heating capacity—of any other gaseous mixture. Thus in the case of a ten-tube boiler, on which our original experiments were made, the consumption of coal-gas was about 1,000 cub. ft. per hour plus about 5,500 cub. ft. or 6,000 cub. ft. of air.

* Abstract of lecture delivered before the North-east Coast Institution of Engineers and Shipbuilders, February 21st, 1913.

This will convey an idea of the extremely rapid rate at which the mixture is caused to traverse the tubes.

After the burnt products have traversed the boiler tubes, and at their point of exit therefrom, it is found that their temperature is never more than about 70° C. (say, 125° Fah.) above that of the water in the boiler, which, of course, depends upon the pressure at which the steam is being generated; this is obviously a much lower temperature than that at which the products of combustion usually pass away from a multitubular boiler. But in order to increase still further the efficiency of steam-raising, the products are passed through a short tubular feed-water heater constructed on the same principle as the boiler.

Results obtained with the Ten-tube Experimental Boiler at Leeds.—In order to give you an idea as to the remarkable "efficiency" of the new system, I cannot do better than detail the results of a trial with one ten-tube experimental boiler at Leeds, which was subsequently exhibited in actual work at Olympia, London, in November last, when fired by means of coal-gas at one experimental station. The connections to the front of the boiler consisted essentially of a tube for the supply of gas and another for the supply of air. The gas and air were mixed before entering the feeding-chamber, which was attached to the front plate of the boiler;

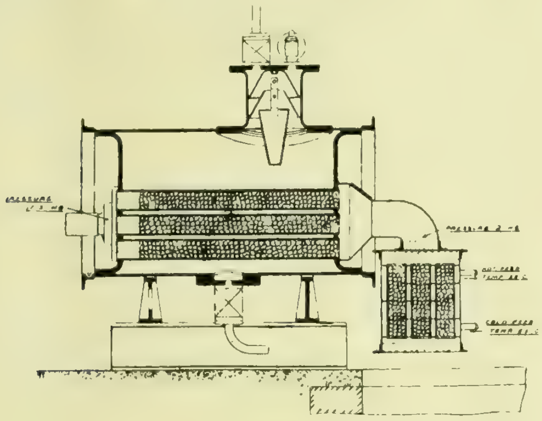


FIG. 6.

the gaseous mixture was burned in the tubes of the boiler; the products passed outwards at the other end into a small chamber, and from thence into the feed-water heater. The latter contained nine tubes, each 1ft. in length and 3in. diam., which were filled with granular material to effect the exchange of heat.

The mixture of gas and air was passed into the feed-chamber of the boiler at a pressure of 17·3in. water gauge. This pressure was necessary in order to overcome the resistance of the packing of the tubes to the passage of the gases through them. The pressure of the products entering the tubes of the feed-water heater was 2in. water gauge. In carrying out the test, the water was evaporated at a pressure of 100lbs. per square inch above that of the atmosphere. The temperature of the boiling water was therefore 168° C. (or 337° Fah.). The temperature of the combustion products leaving the boiler tubes was 230° C. (or 446° Fah.). The average temperature of the products leaving the feed-water heater was 95° C. (or 203° Fah.). The temperature of the water entering the feed-water heater was 5·5° C. (or 42° Fah.), and it was heated to 58° C. (or 136·4° Fah.) before entering the boiler—entirely at the expense of the burnt gases.

Let us now consider the heat-balance of the boiler during the test. The amount of coal-gas fed into the boiler, expressed as dry gas at 0° C. and 760 mm., was 996 cub. ft. per hour. The net calorific value of the gas was 562 B.Th.U. per cubic foot, so that the total heat supplied to the boiler in terms of the net calorific value of the gas was 559,800 B.Th.U. per hour. As to the amount of water evaporated, the following figures apply to the combination of the boiler with its feed-water heater, because the two really comprise one steam-raising system. The temperature of the feed-water was 5·5° C., and the steam was being raised at a pressure of 100lbs. per square inch above that of the atmosphere. The actual amount of water evaporated was 450·3lbs. per hour, which in terms of water evaporated from and at 100° C. (212° Fah.) would be 550lbs. per hour. The actual heat therefrom transmitted to the water was 450·3 × 1,172 = 527,800 B.Th.U. per hour. Therefore, the ratio between the heat transmitted to the water and the net heat of combustion of the gas burnt was 0·943. The figures for this trial are tabulated below.

Trial of Ten-Tube Boiler with Feed-Water Heater.

Fired by Leeds Coal Gas.	Dec. 8th, 1910	
Pressure of Gaseous Mixture entering Boiler Tubes	17·3 W.G.	
Pressure of products entering Water Heater	2·0 W.G.	
	Cent.	Fah.
Boiling Point of Water at 100lbs. per square inch above atmosphere	170·0	338·0
Temperature gases leaving boiler tubes	230·0	446·0
Temperature gases leaving feed water heater	95·0	203·0
Temperature water entering feed-water heater ..	5·5	42·0
Temperature water leaving feed-water heater	58·0	136·4
Evaporation from and at 100° C. per square foot of heating surface per hour	21·1lbs.	
Gas burnt per hour (at 0° C. and 760 mm.)	996 cu. ft.	
Net. cal. val. per cubic foot (at 0° C. and 760 mm.)	562 B.Th.U.	
Heat supplied to boiler	559,800 B.T.U. per hour	
Temp. feed water	5·5° C.	
Pressure of steam	100lbs. per sq. in. above atmos.	
Water evaporated	450·3lbs. per hr.	
Water evaporated from and at 100° C. per hour ..	550lbs.	
Heat transmitted to water	450·3 × 1172 = 527,800 B.T.U.	
Ratio $\frac{527,800}{559,800}$	0·943	

It is one of the outstanding merits of the new system that we are able to burn the gas completely with a minimum excess of free oxygen, and during the test in question the average proportion of carbon dioxide in the combustion products was as much as 10·6 per cent., whilst the oxygen was as low as 1·6 per cent. A most careful examination of the products failed to reveal the presence of even the slightest trace of carbon monoxide, hydrogen, or methane. Therefore the remainder of the gas was simply nitrogen. Even with as little as 0·5 per cent. of oxygen in the products the combustion of the gas in the tubes is perfect, not a trace of combustible gas escaping. The full analysis of the flue products is shown below:—

Analysis of Flue Products.

	(1)	(2)	
CO_2 ..	10·5% ..	10·8%	
O_2 ..	1·8% ..	1·4%	
CO ..	nil ..	nil	No unburnt gas.
H_2 ..	nil ..	nil	
CH_4 ..	nil ..	nil	
N_2 ..	87·7% ..	87·8%	

The 110-tube Boiler erected at the Skinningrove Ironworks in Cleveland, Yorkshire.—Before describing more recent developments of steam-raising by means of surface combustion, I may be perhaps permitted to make a brief historical statement. Our original experiments were made from 1909-10 with simple tubes disposed horizontally in an open trough of water, and therefore evaporating water at atmospheric pressure. With such simple apparatus the great thermal efficiency of the process was immediately demonstrated, and much valuable data obtained. During the summer of 1910, the ten-tube experimental boiler, whose performance I have just described, was erected to the designs of Mr. Michael Longridge, who from the outset had evinced a lively interest in the work, and to whom we were indebted for much valuable advice and encouragement. Six months' continuous experience with this experimental unit gave us great confidence in its reliability and safety, so that when in the early months of 1911 we received an enquiry from the Skinningrove Iron Company, Ltd., for a boiler about ten times the capacity of the experimental unit, to be fired by means of the surplus gas from their new Otto by-product coking plant, we had no hesitation in accepting a commission to install our first large boiler there, under a strict guarantee as to its output and efficiency. This boiler, which was built by Messrs. Richardson & Westgarth, Ltd., of Middlesbrough, to the design of Mr. Michael Longridge, consists of a cylindrical drum 10ft. in diameter and 4ft. from front to back, traversed by 110 steel tubes, each of 3in. internal diameter, which are packed with fragments of suitable refractory granular material. To the front of the boiler is attached a

specially designed feeding-chamber which delivers washed coke oven gas at 60° to 70° Fah., and under a pressure of 1in. to 2in. W.G. to each of the 110 combustion tubes; this gas, together with a regulated proportion of air from the outside atmosphere, is drawn, under suction from a fan, through a short mixing tube into each of the said combustion tubes, where it is burnt without flame in contact with the incandescent granular material. The products of combustion, having traversed the 4ft. length of packed tube, pass outwards into a semi-circular chamber at the back of the boiler, and thence through a duct to the tubular feed-waste heater. The fan, which is attached just beyond this feed-water heater and is direct-driven by a 3-phase alternating-current electric motor, sucks out the cooled products (temperature = less than 200° Fah.) and discharges them, through a short vertical duct, into the atmosphere. The arrangement of the whole plant is shown in the accompanying diagram (Fig. 7).

The plant was successfully started up on November 7th, 1911, for a month's trial run—day and night continuously—after which it was opened up for an official inspection by the representative of a boiler insurance company. Everything worked without a hitch during this trial; steam was generated at 100lbs. gauge pressure from a feed-water of about 4° hardness, whilst the average temperature of the waste gases leaving the feed-water heater was reduced to about

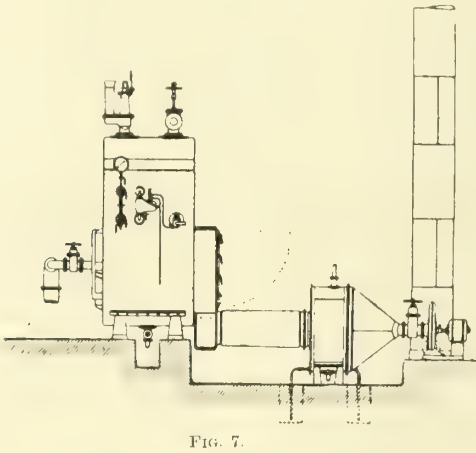


FIG. 7.

170° Fah., a sure indication of the high thermal efficiency of the plant. When, at the conclusion of the month's trial, the boiler was opened up for inspection, the combustion tubes were found to be in good condition and free from scale; indeed, owing to the extremely high rate of evaporation, the scaling troubles experienced with other types of multitubular boilers appear to be completely obviated, the scale being automatically and continuously shed from the tubes in thin films (about $\frac{1}{30}$in. thick) as fast as it is formed; a very important advantage, as anyone who is plagued by scaling troubles will appreciate.

After this official inspection, the plant, having amply fulfilled our guarantee, was taken over by the Skinningrove Iron Company, and it was at once re-started under the direction of Mr. E. Bury, M.Sc., the manager of the Coke Oven Plant, who maintained it in continuous commission for three months until the great coal strike of last year brought everything to a standstill. During this time the plant had worked satisfactorily and had fulfilled every expectation. In July last, after altogether five months' actual running, some further trials were made, during which an average evaporation of practically 5,000lbs. (actually 4,959lbs.) from and at 212° Fah. per hour (steam gauge pressure = 96·9lbs. per square inch) was maintained, the temperature of the waste gases leaving the boiler tubes being 388° Fah., and leaving the feed-water heater being 203° Fah. The power used by the fan was 7·8 h.p. At the conclusion of the July trials one of the boiler tubes, which had been in five months' continuous use day and night, was cut out and subjected to severe mechanical tests, comparative tests being made simultaneously with a new and unused boiler tube of same form and dimensions; the results of these tests, which are detailed below, proved that five months' continuous service had not appreciably impaired the mechanical properties of the boiler tube, thus falsifying the confident predictions of many candid critics of our system. Perhaps the best testimonial to the success of our initial experiments with large boilers is the fact, which I am permitted to mention, that the Skinningrove Iron Company have recently ordered a second boiler for their new battery of coke ovens, now in course of erection, and by June next I hope to see both boilers working side by side.

	*New (unused) Tube.	Old (used) Tube after Five months' Service. Front End of Boiler.	Old (used) Tube after Five months' Service. Back End of Boiler.
Ultimate tensile strength, tons per square inch	25·3 to 27·1	27·9 to 29·6	29·7 to 31·6
Elastic limit	11·9 ,, 14·4	20·05	19·3 ,, 20·5
Per cent. elongation 8"	23 ,, 24	19 to 21	18 ,, 23
Per cent. area contraction ..	55·6 ,, 58·8	61·3 ,, 63·1	53·4 ,, 61·3

* This new tube was slightly thinner than the old tube, and so perhaps the better comparison would be between the results obtained for the specimens taken from the *front* and *back* ends of the old tube, because the *front* end would surround the "zone of combustion" in the tube, whilst the *back* end would never have been subjected to a higher temperature than the water in the boiler. The results prove beyond all question that even the *front* end of the boiler tube, surrounding the zone of combustion, had never been overheated.

General Considerations about the Boiler.—I have perhaps said enough already about the boiler and its working to convince you that it at least gives promise of combining structural simplicity, high thermal efficiency, and concentration of power in a unique degree, but there are certain important general considerations which ought to be further discussed. First, from the constructional point of view, what could be simpler or more compact than a cylindrical shell only 4ft. long by 10ft. in diameter, traversed by straight tubes, supported on a casting, and requiring neither elaborate brickwork setting or expensive chimney flues and stack. Secondly, it has a further advantage over all multitubular boilers in that the front plate can never be heated beyond the temperature of the water, however much the firing may be forced—a circumstance which, coupled with the extremely short length of the tubes, implies an absence of strain and greatly reduces the risk of leaky joints. Thirdly, the high rate of mean evaporation obviates scaling troubles, and the very steep evaporation gradient along each tube causes a considerable natural circulation of water in the boiler, a factor of great importance from the point of view of good and efficient working; in this connection I may remind you that under normal working conditions we obtain a mean evaporation of 20lbs. per square foot of heating surface per hour, and can, if need be, force this up to 35lbs.; of this total evaporation, 70 per cent. occurs over the first third length of the tube, 22 per cent. over the second third, and only 8 per cent. over the last third. Fourthly, inasmuch as each tube of the boiler is, so to speak, an independent combustion unit, capable of being shut off or lit up without affecting the others, and as it only takes five minutes after lighting up a cold tube to attain its maximum steam output, it is obvious that not only is such a boiler highly responsive to rapid variations in the load, but also it works with equal efficiency at both small and big loads; indeed, within very wide limits, its efficiency is practically independent of the load.

The revival or, if I may so term it, rediscovery of incandescent surface combustion, with which my work has become associated in the public mind, has perhaps come as a timely reminder that the science of combustion is not yet a completed record; a new chapter has been begun and doubtless will be further added to by successive workers. On the theoretical side, there are still obscure points concerning the mechanism of "surface combustion" for future investigation, and it will probably take many years of unremitting work to realise the wide range of industrial possibilities in gas-firing already opened up, whilst the equally important problem of "oil-firing" still awaits solution. The number of applications of "surface combustion" which have been pressed upon our attention from without is positively embarrassing, and the task of fulfilling all expectations in the near future is indeed formidable.

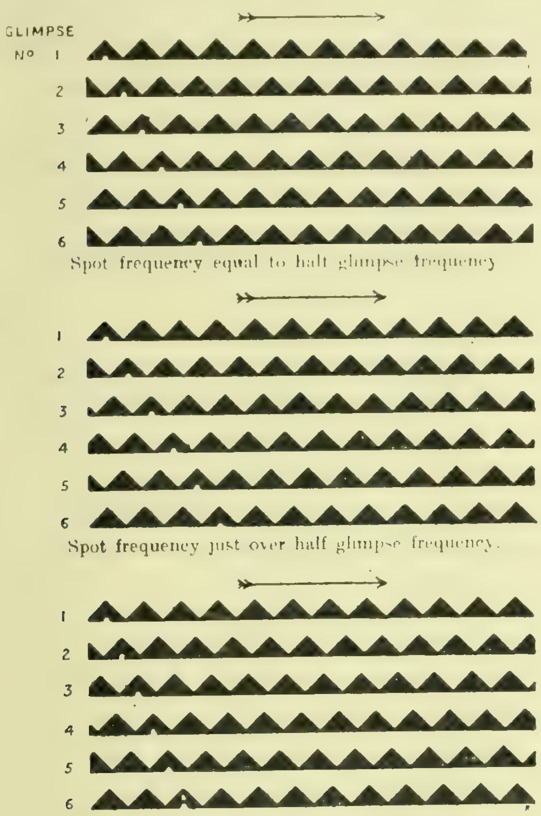
Manchester International Exhibition, 1914.—Arrangements are being made to hold an international exhibition in Manchester next year.

THE STROBOSCOPE IN SPEED MEASUREMENTS AND OTHER ENGINEERING TESTS.*

BY PROF. DAVID ROBERTSON, D.SC.

(*Concluded from page 515.*)

Sub-multiple Speeds. — When running at half the primary speed, the spots move only one half the pitch during the glimpse period (see Fig. 8). The pattern is thus seen in the same position at every other glimpse, the images of the marks seen at the even glimpses being midway between those formed at the odd ones. The two sets of images are superimposed,



Spot frequency equal to half glimpse frequency

Spot frequency just over half glimpse frequency.

Spot frequency just under half glimpse frequency

FIG. 8.—ACTIONS NEAR HALF PRIMARY SPEED.
(One mark is notched to show the actual motion.)

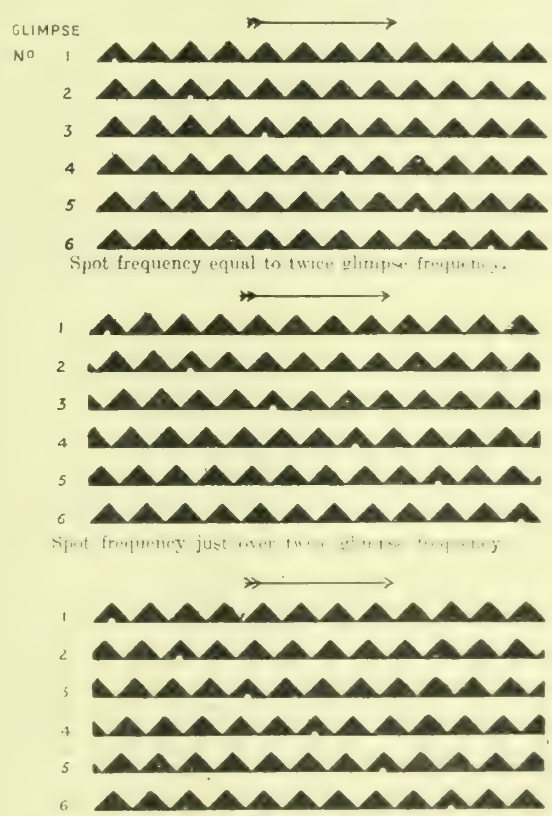
and the result is again a stationary pattern, but the number of marks seen is twice the actual number. Except where they overlap, the images are fainter than at the primary speed, for each is formed by an impression received at every second glimpse. In the same way, patterns with 3, 4, 5, &c., times, as many marks as there are real ones, are seen when the speed is $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, &c., of the primary speed, each image being formed by impressions received every 3rd, 4th, 5th, &c., glimpse. The limit of multiplication is reached when the pattern becomes too fine to be visible, when the interval between successive impressions is too great for persistence of vision, or when the pattern is hidden by the overlapping of marks of unsuitable shape.

When the speed is not quite right, the apparent motion of the spots is the same as if their actual number were increased to that appearing on the pattern, which is that number for which the synchronous speed would be the primary one. Consequently the equations already given (1) and (2) will still hold if n be taken as the apparent number of spots. With the same proportional error from any of these speeds the same slip of the spots is obtained as with the primary speed. These will be referred to as sub-multiples of the primary speed. They may be distinguished from one another by counting the marks on the pattern, but as this is usually impracticable, it is better to use spots of such a shape that the order of the sub-multiple can be directly counted, as described later. With the fork referred to already and the disc of Fig. 10, sub multiples have been detected up to the 20th order, but only the first eight or so are of real use owing to the fineness of the patterns of higher orders and the difficulty of counting them.

* Paper presented before the Institution of Engineers and Shipbuilders in Scotland, March 18th, 1913.

Multiple Speeds. — Stationary patterns can also be observed when the speed is a multiple of the primary speed. For instance, let it be twice the primary speed. The motion during the glimpse period is then twice the pitch, and at the second glimpse each mark is exactly at the place formerly occupied by the second one ahead (Fig. 9). They consequently appear to be steady, but the definition is not so good as before, because the movement during the time of vision is twice as great. We may imagine this condition of double primary speed to be attained by doubling the number of spots without altering the speed. Obviously when the speed is not quite right this will double the number of marks apparently passing a fixed point; in other words, the slip is that corresponding to twice the actual glimpse frequency, that being the glimpse frequency for which the actual number of spots makes the synchronous speed the primary one.

In the same way, we may get stationary images at 3, 4, 5, &c., times the primary speed, having 3, 4, 5, &c., times as much drawing out, and having the speed errors magnified 3, 4, 5, &c., times, corresponding to glimpse frequencies 3, 4, 5, &c., times the actual glimpse frequency. The upper limit of the order of the multiple which can be observed is set by the increasing drawing out of the images, by the difficulty of finding it, or by the strength of the revolving apparatus. Unless each glimpse be made very short, the images get rapidly fainter as the order is raised. With the 64-spot ring and the tuning fork already referred to, patterns could still be observed at five times the primary speed. The sixth one was beyond the safe speed, but it is probable that it at least could also have been seen. The opening would last for about $\frac{1}{5}$ to $\frac{1}{6}$ of the glimpse period, but the maximum opening would only be for a moment. In the phase displacement experiments referred to below, in which a revolving shutter and a very short glimpse were employed, the speed was 16 times the primary for the 64-spot ring, and the pattern was still fairly sharp. Matters were, however, simplified in this case by the fact that the shutter was driven by a synchronous motor, otherwise it would have been difficult to set the speed, for an error



Spot frequency equal to twice glimpse frequency.

Spot frequency just over twice glimpse frequency

Spot frequency just under twice glimpse frequency

FIG. 9.—ACTIONS NEAR TWICE PRIMARY SPEED.
(One mark is notched to show the actual motion.)

of 1 per cent. would cause 15 spots per second to pass. For multiples of the primary speed we must write:—

$$f_s = n N - m f_g = m\left(\frac{n}{m} N - f_g\right) = n (N - N_s) = \frac{N - N_s}{N_s} m f_g \qquad (3)$$

$$\text{And } N = \frac{m f_g + f_s}{n} = N_s + f_s / n \qquad (4)$$

where m is the order of the multiple. Equation (3) shows that the slip is proportional to the order, as was already shown.

Just as it is possible to have stationary patterns at sub-multiples of the primary speed, so also they are observable at sub-multiples of the multiple speeds. These are related to the multiple speeds in exactly the same way as the former ones were to the primary. The number of speeds at which stationary patterns can be obtained with suitably shaped marks is thus very great, being all possible sub-multiples of the primary speed for the given glimpse frequency, and of those for 2, 3, 4, 5, &c., times that frequency up to the limits of visibility, which may be raised as high as desired by having sufficiently short glimpses and a sufficiently delicate control of the speed. In the experiments already referred to with the disc of Fig. 10, 20 different patterns could be recognised on one ring below its synchronous speed, and 25 above, making 45 in all. Even sub-multiples were more easily seen than odd ones of similar, or even lower, order, but this may have been due to some peculiarity in the adjustment of the slits of the fork.

Multiples of the primary speed cannot be distinguished by themselves. They must be counted as they appear while the speed is being gradually raised above the primary speed. If, however, the approximate speed is known it is easy to settle which multiple is being used. Such an approximation can often be obtained from the appearance of other rings with different numbers of marks. Multiple speeds have the advantage that they give an even speed scale, while the sub-multiples do

FIG 10.—CONVENIENT STROBOSCOPIC DISC FOR RUNNING-DOWN TESTS.

not. Thus with 100 spots and a glimpse frequency of 10,000 per minute, there would be a stationary pattern at every 100 revolutions per minute. The difficulty is to tell one from another. By making the even marks different from the odd ones, which is equivalent to having also a 50-spot ring, the even hundreds could be distinguished from the odd ones. A ring of 20 spots, or every fifth mark of a different pattern from the others, would distinguish the 500s and so on; 12,000 per minute would require 120 spots, and this could be more sub-divided than the 100, and so allow a greater number to be identified with certainty.

Patterns at speeds derived from multiples can be distinguished from those derived from the primary speed by their faintness and the difficulty of catching them. They generally show a sort of open lattice pattern, and may have only half the number of peaks corresponding to the order of their sub-multiple. It is hardly safe to rely on counting with them, but their position on the speed scale given by their relation to the synchronous speeds on other rings aids in identifying them. The difference between the derivatives of the primary and multiple speeds is well brought out while the disc is stopping, as in a running-down test. The primary speed and its sub-multiples can be seen approaching or receding for a considerable time on either side of synchronism. The double speed and its sub-multiples give much less warning and more quickly pass away, while those derived from the higher multiples, if seen at all, flash up for a moment and then are gone.

When the disc is constantly illuminated, the individual spots can be momentarily detected up to fairly high speeds by a sudden involuntary movement of the eye. It is difficult to do this purposely, as the eye tends to look at what the observer is trying to see. If the eye be kept steadily fixed on one place, the spots fail to be seen individually at about 10-15 per second, but their motion is apparent up to about 30 per second, when they merge into a continuous grey. Practically the same limits apply to the visibility of the apparent motion of the spots when seen stroboscopically. It is quite a common thing to see a ring of spots apparently revolving both ways at once, and it is even possible to have three patterns on one ring visible at the same speed. In the latter case, however, the eye can usually only see one at a time; if the speed be synchronous for the middle one, the others will rotate in opposite ways, and the eye can pick out any one of the three and follow it, just as it can either see a pile of solid cubes or one of hollow cubes, according to the first impression, in a well-known delusion. Faint patterns coming in the neighbourhood of a strong one are generally entirely masked by the latter. If the glimpses are too sharp, so many things are visible at once that the disc is quite bewildering, and it is almost impossible to identify many patterns with certainty. Hence it is best to have sufficient sharpness to show up the patterns wanted, but no more.

Stroboscopic Patterns.—Most experimenters have confined their attention to circular, rectangular, or radial marks, but they have, as a rule, only wanted the primary speed for which the shape of the marks is of no importance, and one is as good as another. But for a speed indicator it is necessary to have as many known speeds as possible, and it is best to employ such a shape as will enable these to be recognised most easily. Drysdale advocates a disc with a square, a pentagon, a hexagon, and a ring of 30 triangular teeth, the spaces between these boundary lines being alternately black and white. The author uses a rather different arrangement with specially shaped teeth, having six rings of 12, 13, 14, 15, 16, and 64 teeth (Fig. 10). This gives a conveniently spaced set of speeds, particularly useful for running down tests, the five inner rings being used for the upper speeds and the 64-ring for the lowest ones. The primary speed on the outer ring, being also the quarter speed for the adjacent ring, gives a well-marked change-over point. Allowing for the fact that several speeds are synchronous on two or more rings, there are about 50 useful speeds. This number could, of course, be increased by adding additional rings.

For the periphery of a cylinder, the best shape of spot is an isosceles triangle having the pitch for its base, so that the whole forms a saw edge with black teeth on white ground. Fig. 11 shows the appearance of these spots when they are overlapped at sub-multiples of the primary speed. It will be observed that the number of rows of peaks, which is most easily counted along one of the sloping lines, indicates the order of the sub-multiple. It is much easier to count this than the total number of visible marks, especially when the pattern is not quite stationary. Compared with the primary pattern, the extreme black and white triangles, being seen every glimpse, retain their full brightness, but diminish in size with the order of the sub-multiple. Unless the glimpses are too sharp, sub-multiples of multiple speeds can never be mistaken for those of the primary, as they are much less definite and appear to be hollow.

If the triangles were arranged round a circle on a flat disc, their bases would be inclined to one another, and the inner part of the overlapping pattern compressed, which makes it more difficult to count fine ones. The best form of boundary line is then made up of arcs of equal left and right-hand spirals, so proportioned as to make the division between black and white change uniformly from the base to the tip. The spiral arcs, however, are sufficiently well represented by circular ones coinciding with them at their extreme and middle points. This gives the tooth the form of a Gothic arch, which is actually easier to draw in than the straight lines. Fig. 12 shows how these spots overlap, giving similar patterns to those obtained with triangular spots moving parallel to their base.

The stroboscopic appearance of a disc, such as that of Fig. 10, while running down is very fascinating. Many very pretty patterns are formed, whose beauty is considerably enhanced if the condenser used for the light has a lot of chromatic aber-

ration. An immense variety of designs can be obtained by varying the form of the spots, or by drawing them in outline only.

Measurement of Slip.—The greatest use that has been made in engineering of the stroboscopic principle is in connection with alternate-current machinery, and particularly for getting the slip of an asynchronous motor. For these purposes, the easiest way to get periodic glimpses of the correct frequency is to employ an arc or incandescent lamp supplied from the same source. The fluctuations of light are sufficient to produce many stroboscopic effects at all lighting frequencies with arc and tungsten lamps, and at low frequencies with carbon lamps.

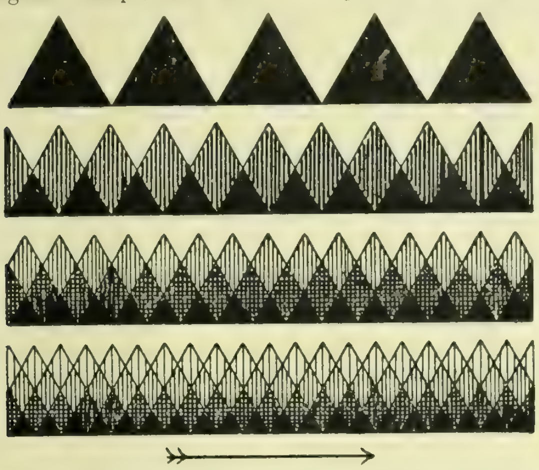


FIG. 11.—OVERLAPPING OF TRIANGULAR SPOTS ON A STRAIGHT BASE.

There is a maximum of brightness for both positive and negative half-waves, and thus the glimpse frequency is twice that of the supply. There is a great want of sharpness, especially with the incandescent lamps, owing to the fact that the illumination only varies between a maximum and a minimum instead of being entirely extinguished during the greater part of each cycle. With the Bristol frequency of 93 per second, the author has found that with the ordinary electric lighting only in use (tungsten lamps) it is easy to pick out the marks for a good bit on either side of synchronism, but that they get lost when synchronism is reached and maintained. Even with an arc on that high frequency, the spots do not show very clearly when apparently at rest.

Van Hoor seems to have been the first to apply this effect to the measurement of slip. Equally spaced marks, one for each pole of the machine, are made on the pulley or other rotating part. At synchronism these would appear to be steady, and at lower speeds they move backwards (apparently), one mark passing a fixed point for each half-cycle lost. The slip is generally obtained by timing the apparent motion of the marks, from which it can be calculated when the supply frequency or the motor speed is known.

Another way, which avoids the measurement of time, is to count the revolutions of the shaft in the ordinary way during the time taken for the marks to slip an exact number of places. The latter number divided by the number of poles gives the revolutions lost; the counter gives the actual number made in the same time; the sum gives the synchronous number; and the ratio of the first of these three to the last is the slip.

Besides its want of sharpness, the arc method has the great disadvantage that the double glimpse frequency makes the greatest slip that can be measured comparatively small. If it is assumed that three spots per second is the maximum that can be counted, then the greatest slip that can be measured in this way is 6 per cent. at 25 cycles per second, 3 per cent. at 50, and $1\frac{1}{2}$ per cent. at 100. The double frequency is an advantage when measuring very small slips.

Tian has increased the range of the arc method by putting a rectifier into the arc circuit so as to cut off one-half wave of current, and the author has tried to do the same thing by superimposing a continuous current on an alternating one. The want of sharpness still remains, and these methods are not less troublesome than the use of an auxiliary motor, and are certainly much inferior to it in use. The effective light frequency can be reduced to that of the supply voltage in a very simple manner by having the arc in an ordinary projection lantern and tilting the carbons well back. Only one crater sends light to the condenser, and so one-half wave of light is almost suppressed. With one mark for each pair of poles, only a faint image is produced by the second half wave.

Drysdale fixed his stroboscopic disc on a separate spindle carried on an arm, which enables it to run on a cone driven by the shaft of the motor being tested. The point of contact between the disc and cone is varied by a screw acting on the carrying arm until the pattern on the disc, which should have the same number of rays as there are poles on the motor, is seen to be stationary when illuminated by the A.C. lamp. The disc is then running at the synchronous speed and the slip is read off from the scale, which has been previously calculated to suit the slope of the cone. This instrument (see Fig. 13) has the advantage that it uses a zero method and that it is direct reading when set. For very small motors it has the drawback of adding an unknown load, but this is obviated in the more elaborate instrument described below.

Except where the original Drysdale indicator is used, it is better not to have an A.C. arc, but rather to follow Benischke (5·01) and employ a rotating shutter driven by a synchronous motor from the A.C. mains, and either look through the shutter at a pattern on the motor tested or use a continuous-current arc, as in Fig. 2. By putting one slit in the shutter for each pair of holes of the auxiliary motor, and one mark on the shaft or pulley of the tested motor for each pair of its poles, the glimpse frequency is reduced to that of the supply, or half that with the simple arc method. Consequently, the measurable range of slip is doubled, and at the same time the sharpness is so much increased that rough chalk marks on the shaft or any other exposed part are quite sufficient for easy observation. If the numbers of poles in the two motors have a higher common factor than 2, the number of slits and marks can be reduced to the quotients obtained after dividing by that factor, if desirable, and so the range of slip can be still further raised. For example, if the auxiliary motor has four poles, and the motor tested any multiple of four, only one slit need be put in the shutter and one mark for each four

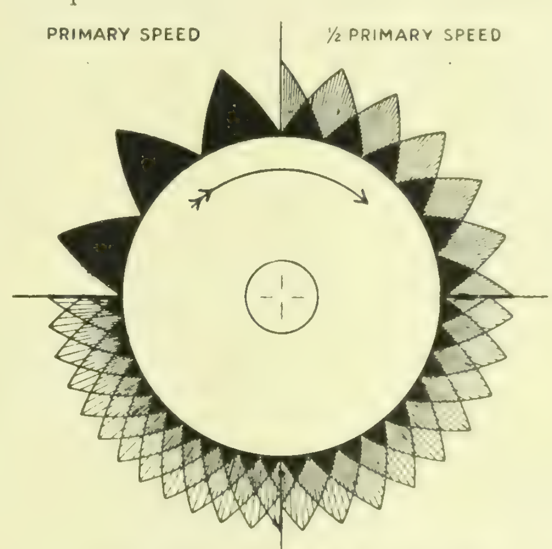


FIG. 12. OVERLAPPING OF GOTHIC SPOTS ARRANGED ROUND A CIRCLE

poles. The passage of one mark will then correspond to a slip of two cycles, and the fractional slip is given by the apparent frequency of the spots passing a fixed point divided by half that of the supply. The small motor provided with the oscillograph outfits is a very convenient one for the purpose, a suitable cardboard or aluminium shutter being put in place of the ordinary one.

Benischke also uses a detachable counter on his auxiliary motor, and keeps it in gear while the slip amounts to an exact number of revolutions, as shown by the movement of the spots. He thus obtains the corresponding slip and synchronous revolutions, and their ratio at once gives the slip, without any measurèment of time.

In his latest slipmeter, Drysdale drives the cone by a synchronous motor and cuts a number of slits in the spinning

disc through which a suitable pattern, carried on the motor being tested, can be observed. The arrangement is shown in Fig. 14. The motor is of the phonic wheel type, in which the rotor is a toothed wheel made up of iron stampings, and the stator a simple laminated electromagnet having two poles at opposite ends of a rotor diameter. The rotor always tends to occupy the position of minimum magnetic reluctance, especially when the flux is a maximum. Consequently, when running at synchronous speed it is subject to forces tending to make it run with the teeth opposite to the poles at the instant of maximum current. It actually lags a little behind this, and so obtains the necessary driving torque. In order to start the motor it is run up to speed by means of a handle, seen at the right of the illustration, which is thrown out of gear when synchronised. The correct speed can be recognised by the hunting sound in a quiet room, but it can be seen optically if the teeth are illuminated from the same supply mains, or near enough by simply setting the disc to the expected slip and observing the pattern on the motor to be tested. It is convenient to have a higher voltage available than that necessary for running, and to cut this down by a rheostat after the hunting has subsided.

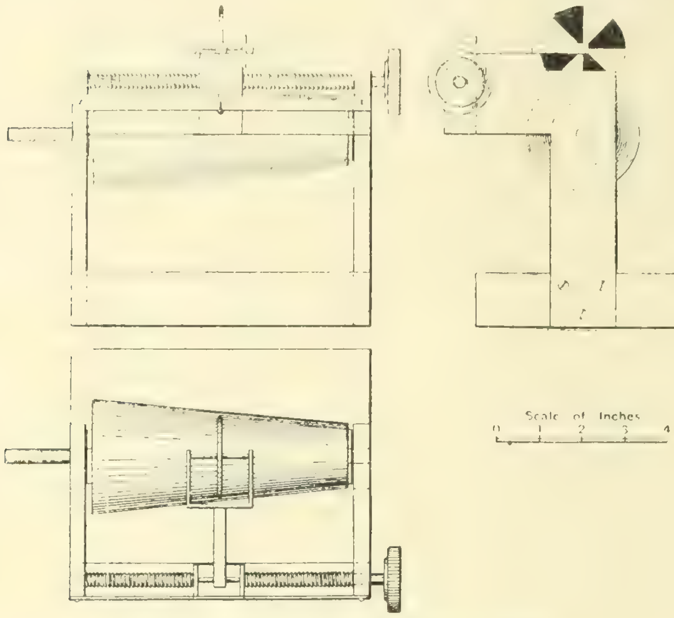


FIG. 13.—DRYSDALE DIRECT-READING SLIP-METER.

The disc has one slit for each tooth of its motor, and the pattern one mark for each pole of the motor to which it is affixed. The disc is moved up or down the cone by means of the handle, which can be seen at the left, until the pattern appears stationary when viewed through the slits. The disc and pattern are then running synchronously with one another, and the slip can be read on the scale. In this instrument the slip is given by the ratio of the difference of the diameters of the disc and cone to that of the disc, and is therefore proportional to the displacement of the disc from the plane, where it runs at the same speed as the cone. That is, the same scale applies as for speed ratio, but the zero is shifted to the point of equal speeds. The method of checking the scale has already been described in connection with speed measurement. Greater sensitiveness in obtaining a balance can be obtained by having, say, five times as many slits and increasing the number of marks on the pattern to five times the number of poles. The effect of this is to give a finer scale on which the apparent motion can be observed more easily.

A number of other stroboscopic methods of determining slip have been proposed, involving the use of synchronous reeds driven from the supply, and lamp filaments lighted by the alternating current and caused to vibrate synchronously by being placed in a constant magnetic field. None of these appear to be so good as the direct counting methods or the Drysdale indicator.

Phase Swinging of Synchronous Machines.—A synchronously rotating shutter and the stroboscopic disc are also useful for observing and measuring the phase displacements which occur in a synchronous machine when the load or field current is varied, when synchronising, and when hunting occurs. The number of slits in the shutter and the number of marks on the disc are not of great importance this time, but it is convenient to have one glimpse per cycle and one ring having one mark per pair of poles. The mark may form a pointer reading on a fixed scale, or more conveniently, as it avoids all parallax, the scale may be marked on the stroboscopic disc and the shadow of a fixed wire used as a pointer. It is necessary to see that the auxiliary motor does not itself hunt; if it does, its oscillations can generally be recognised by their high frequency.

The disc of Fig. 10, with the addition of four equally-spaced marks outside the 64-ring, serves very well for an 8-pole alternator. The four marks show the normal position and the 64-ring serves as a scale on which the displacements can be measured. Each division corresponds to $\frac{1}{16}$ cycle, or $22\frac{1}{2}°$ of phase. Although the speed is 16 times the primary speed for this ring, the marks can be seen quite clearly. In this way, the author has obtained, by direct measurement, the relation between the load on an alternator and its phase displacement relative to the mains voltage. The scale had divisions corresponding to 10° of phase and was illuminated with one flash per cycle. With a very narrow slit in the shutter the divisions could just be seen. Greater distinctness could be obtained with a still narrower slit if the number of flashes per cycle be also increased, in order to get enough light, to 4, 6, or 12. This would also multiply the special marks put to distinguish the poles. Changes of phase with change of load or of field current amounted to about 30°, and were easily observed; the gradual decay of the oscillations set up when these alterations are made suddenly are beautifully shown and easily measured, but the most interesting phenomena are obtained on synchronising. The way in which the relative phase of machine and mains (the ordinary lighting mains of the city) change when they are not paralleled but the speed is right is most interesting; often the phase remains constant for quite a long time and then suddenly starts changing as some load is put on somewhere on either the alternating-current or the direct-current mains.

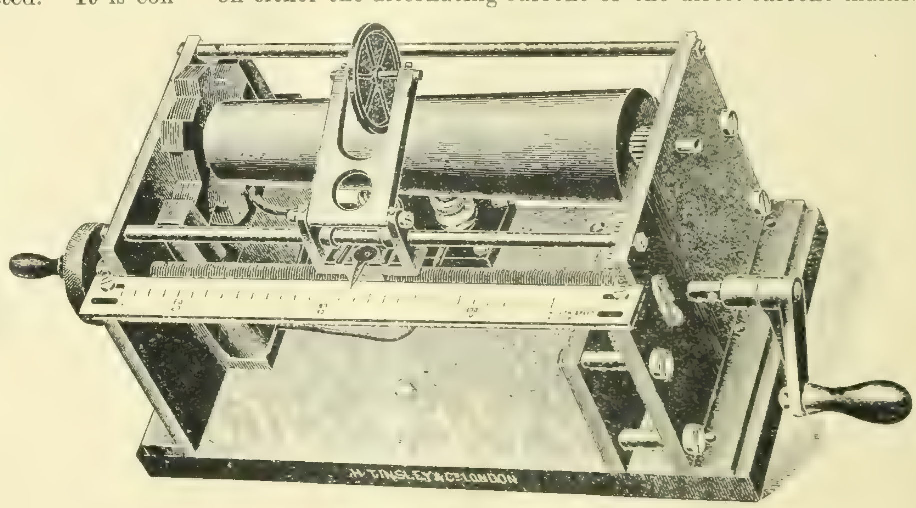


FIG. 14.—DRYSDALE DIRECT-READING SLIP-METER. MOTOR DRIVEN PATTERN.

The way in which the machine can be seen to jump into step on switching into parallel with the mains is most instructive, especially if the shot is a bad one. About 90° out of the correct phase seemed to produce the most violent oscillations; when switched on near contrary phase (the machine is quite a small one, 5 kw.) it hesitates before deciding whether to jump a pole or slip one, but the oscillations do not seem to be worse than when only $\frac{1}{4}$-cycle out, although the ammeter reading is a good deal more. Hunting due to any cause can be detected, and its amplitude read off on the scale.

Speed Fluctuations.—The fluctuations of speed dealt with in the previous section are comparatively slow, and can be easily

followed with the arrangements described. In a similar way, the cyclic variations in the speed of a very slowly moving shaft can be detected. For instance, that due to the finite number of commutator segments in certain types of meters can be quite easily seen at the lower loads. With more rapid rotation, however, the fluctuations occurring within a single revolution are much more difficult to show. Even if a large number of glimpses per revolution be used, with the corresponding number of marks on the disc, the only result would be an oscillation of the pattern too rapid to be seen. It is, therefore, necessary to make a second application of the stroboscopic principle, and to examine the picture itself stroboscopically. The author is not aware of anyone hitherto having succeeded in directly showing the speed fluctuations, but he puts forward the following method as one which has some probability of success.

Let the rotating body whose motion is to be studied be provided with a stroboscopic ring of n teeth, and let the glimpse period be $(1 + 1/n)$ times the time of one revolution. The pattern will appear stationary, but as each successive glimpse catches the marks one place further forward (+) or behind (−), if one of the marks be made different from the rest that one will be seen to rotate slowly in the time actually taken to make n revolutions. Thus the actual changes in one revolution are made to take place, apparently, in n revolutions, that is, n times as slowly as they actually happen. Consequently by making n large enough the change can be followed by the eye. It would probably be impossible to keep the speed of the shutter accurately equal to the mean

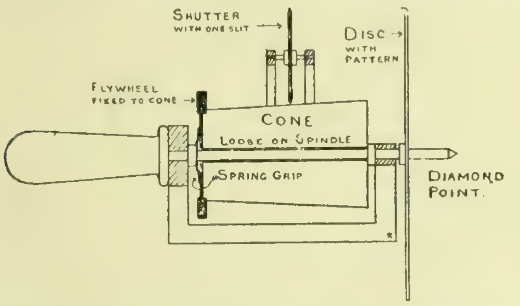


FIG. 15.—PRINCIPLE OF PROPOSED SPEED FLUCTUOMETER.

speed of the body with an independent drive, but the Drysdale slip indicator can be modified for the purpose.

Add a flywheel to a Drysdale cone of small slope, and mount the combination loosely on the spindle, with a light spring friction clutch, if necessary, to give sufficient driving torque. When the spindle is connected to the shaft to be tested, the flywheel and cone will assume the mean speed of the shaft. The cone drives a shutter with one slit; the disc with n marks; one different from the rest is fixed on the shaft under test, or on the spindle of the instrument driven by it. Beginning with the shutter running at the same speed as the cone, gradually lower its speed until the next steady, or oscillating, pattern is observed. These oscillations are due to the speed fluctuations. By adjusting the speed of the shutter to one side of the value considered above, the pattern can be brought to rest for any desired position of the index mark, and so the exact speed at that point in the revolution can be determined. The proposed arrangement is shown in Fig. 15.

Most of the arrangements for experimenting on speed fluctuation involve a measurement of the relative displacement of the shaft and another rotating uniformly with its mean speed. Indeed, for some purposes, such as the driving of alternators, it is the amount of this displacement that matters and not the actual speed changes. If the latter are required, they must be calculated from the displacements. As a rule the flexibly driven flywheel is used to get the mean speed, but in some cases an independent electric drive has been employed.

When the fluctuations are great and the speed not too low the following simple method may be used for demonstrating them and for very rough measurements. Put a single pointer-shaped mark radially on a disc attached to the shaft to be examined and drive a stroboscopic shutter by any convenient means so that any exact number (the more the better) of glimpses occur each revolution of the machine under test. A star will be seen with as many rays as there are glimpses per revolution. With uniform speed, these rays will be equally spaced; but if the speed fluctuates, the rays will appear further apart where it goes fast, and closer together where it goes slow. A modification of this idea is to divide the radial length into n parts, and distribute them round the circles so that their centres lie on equally spaced radii. When seen with n sharp glimpses per revolution a perfect star of n rays will appear if the speed be uniform; if it is not, the different portions of the rays will not register with one another.

Most of the stroboscopic methods proposed are really instantaneous photograph methods, using often a zoetrope cylinder on the shaft, and sometimes another revolving shutter. Sartori, however, gives a simple and direct method for getting the displacement from mean rotation. His shaft and flywheel each carry a blackened glass disc, placed close together. Right and left-handed evolutes are traced through the black; a source of light is placed on one side and the discs are viewed from the other. The light only gets through at the crossing point of the two curves, and the distance of this point from the centre changes with the relative positions of the two discs in a known way. When the arrangement is rotating the bright point will trace out a closed curve and be seen as such. The curve will be a circle if there be no change in the relative positions of the two discs in a revolution, but if there is any such change it will be indicated by the shape of the curve, which can be measured or photographed.

In addition to the optical methods to which the paper is confined, a number of electrical contact methods are in use for determining wave-form, slip, &c., on the lines of that first introduced by Joubert. Although not stroboscopic in the narrower sense of the word, they employ exactly the same principle but use an intermittent flow of electricity instead of an intermittent passage of light.

ELECTRIC SUPPLY IN LONDON.*

BY FRANK BAILEY, M.INST.C.E.

THE supply of electrical energy has now developed from being a luxury to a practical necessity. The use of electrical energy as the motive power of our tube and other railways, the working of our factories, and for lighting, heating, cooking, &c., has become so general that few of those who now participate in its advantages realise the difficulties that were experienced in the early days of pioneering a new industry. The pioneering days from 1880 to 1890 saw many difficulties—statutory, technical, and financial. The Electric Lighting Act of 1882 recognised the birth of a new illuminant and the possibility of its commercial application, but owing to reasons which are now difficult to explain or appreciate, the Act limited all Provisional Orders to a period of 21 years. This short period did not encourage enterprise, and strenuous efforts to secure a sounder basis for the building up of a great enterprise resulted in the passing of the Electric Lighting Act of 1888, which extended the period to 42 years.

Useful pioneering work was, however, accomplished between 1882 and 1888, and public interest was kept alive by many works undertaken by private enterprise with a view to perfecting the generation and distribution of electric supply. Up to the year 1890 none of the London vestries—now merged into borough councils—had decided to embark on municipal trading, with the exception of the St. Pancras Vestry, who had then started to equip their own works for electrical supply; and it was not until the commercial success of the various undertakings had been established that 13 of the remaining borough councils in London applied for and obtained Provisional Orders. We ought therefore to appreciate the enterprise of the 13 companies who had undertaken the responsibilities of carrying out the obligations imposed upon them by the terms of the Provisional Orders granted under the Act of 1888. These companies had to raise the capital they required without being able to quote actual experience of a profitable yield; and it is remarkable, considering the inexperience of the industry at that time, how few mistakes were made, and how well the capital was expended. Most of the early pioneering plants have now disappeared, the capital cost having been redeemed out of revenue; in many cases small works in unsuitable positions

* Abstract of paper read before the Royal Society of Arts, April 9th, 1913.

being utilised for other purposes, and the output supplied from larger works with facilities for improved plant.

Table I. gives, in a summarised form, the present position of the various supply authorities in London. This table shows the output for the 14 local authorities who work their own Provisional Orders, as published for the municipal year ending March 31st, 1912, and as estimated for the year ending March 31st, 1913. The output given for the 13 companies is taken from the published accounts, supplemented in many cases by information kindly supplied. The total output includes some supplies given for railway and tramway purposes within the area of the County of London, which, according to the census returns of the year 1911, contains 74,816 acres and a population of 4,521,685 persons.

TABLE I.—*Electric Supply in London.*

Local authority.	Capital expended.	Units sold. 1911.	Units sold. 1912.	Max. load. Winter, 1912–13.
	£		Estimated.	Kw.
Battersea	298,038	4,288,000	6,200,000	3,050
Bermondsey	181,172	4,144,438	4,600,000	1,960
Fulham	281,008	3,331,497	3,900,000	2,170
Hackney	356,394	6,615,526	9,800,000	4,290
Hammersmith	344,153	9,335,892	9,600,000	5,900
Hampstead	437,000	4,794,413	5,240,000	3,290
Islington	513,462	6,416,953	8,000,000	4,930
Poplar	302,468	9,193,872	12,000,000	5,250
Shoreditch	379,619	6,994,710	9,000,000	4,680
Southwark	108,673	1,790,983	3,000,000	1,700
Stepney	426,777	11,972,955	14,000,000	6,500
Stoke Newington	36,000	426,527	475,000	320
St. Marylebone	2,069,823	13,488,698	15,000,000	9,700
St. Pancras	557,468	9,452,067	11,376,000	3,740
Woolwich	310,000*	2,198,569	2,517,000	1,650
	£6,602,055	94,445,100	14,708,000	59,130
Company.				
Brompton	276,042	2,868,817	3,029,883	1,890
Charing Cross	2,340,762	27,118,199	27,657,296	13,990
Chelsea	490,301	4,016,478	4,184,072	2,800
City	2,000,324	26,633,759	27,488,860	18,510
County	1,885,648	20,450,787	22,512,478	12,800
Kensington	388,709	5,821,514	5,727,896	3,640
London	1,345,883	20,476,982	28,409,755	13,500
Metropolitan	2,103,996	13,567,501	15,666,247	11,260
Notting Hill	249,608	2,336,849	2,482,414	1,630
South London	403,310	4,479,487	5,000,118	3,130
South Metropolitan	624,949	4,855,580	5,481,346	4,000
St. James'	426,398	10,708,689	11,044,768	5,950
Westminster	1,252,630	19,868,622	18,638,125	10,880
Central (St. James' and Westminster Joint)	600,296	—	—	—
Wood Lane (Kensington and Notting Hill Joint)	224,340	—	—	—
	£14,613,196	163,203,264	177,323,258	103,980
Grand totals	£21,215,251	257,648,364	292,031,258	163,110

* Estimated.

NOTE.—Local authorities' accounts made up to March 31st each year. Companies' accounts made up to December 31st each year.

To complete the statement so as to include all electric supply, reference must be made to the various railways and tramways operated by electric traction. The Metropolitan District Railway, and many of the tube railways, are supplied from the Lots Road power-house; the Metropolitan Railway from the Neasden power works; the Great Western Railway (Hammersmith and City branch) from its own works at Park Royal; the London, Brighton, and South Coast Railway (Crystal Palace section) from the works of the London Electric Supply Corporation at Deptford; the Waterloo and City Railway, vested in the London and South-western Railway Company, from works at Waterloo; the Great Northern and City Railway from its own works; and the Central London Railway from works at Shepherd's Bush. Important works are in progress by the London and North-western Railway for the erection of a power-house and for the electrification of local lines, and by the London and South-western Railway Company for the electrification of suburban lines, while other railways have schemes in contemplation.

The disappearance of the horse for all tramway purposes in London is now nearly complete, and is another achievement of electric supply. This branch of the application of electric power must appeal to all, for the tramcar, although not an object of beauty, has penetrated to distant suburbs and surrounded London. The Greenwich power-house, erected by the London County Council, contains many of the best features of the combined experience of other countries, and supplies nearly the whole of the tramway system.

The total amount of electrical energy utilised for all purposes may be estimated for the year 1912 as follows:—

	Units.
Railways	271,500,000
Tramways	130,000,000
General Supply	277,500,000
Total	679,000,000

The progress of the supply authorities is shown graphically by the curves, Fig. 1, indicating the maximum demand and output in units. The influence of the advent of the metal filament lamp is shown by the lighting output, any temporary depressing effect being more than neutralised by the increase in the sale of units for power purposes. The future demand for increased illumination from existing wiring, and the necessity for providing all the buildings with the necessary means for utilising this most efficient and economical light, shows signs of steadily increasing and exceeding all estimates based on the old carbon filament lamp. Between the years 1889 and 1904 every unit sold at from sixpence to eightpence could be utilised to obtain light up to 250 c.p. for one hour by using carbon lamps, or say, 36 c.p. hours for one penny; now, by using the tungsten lamp at the present moderate charges

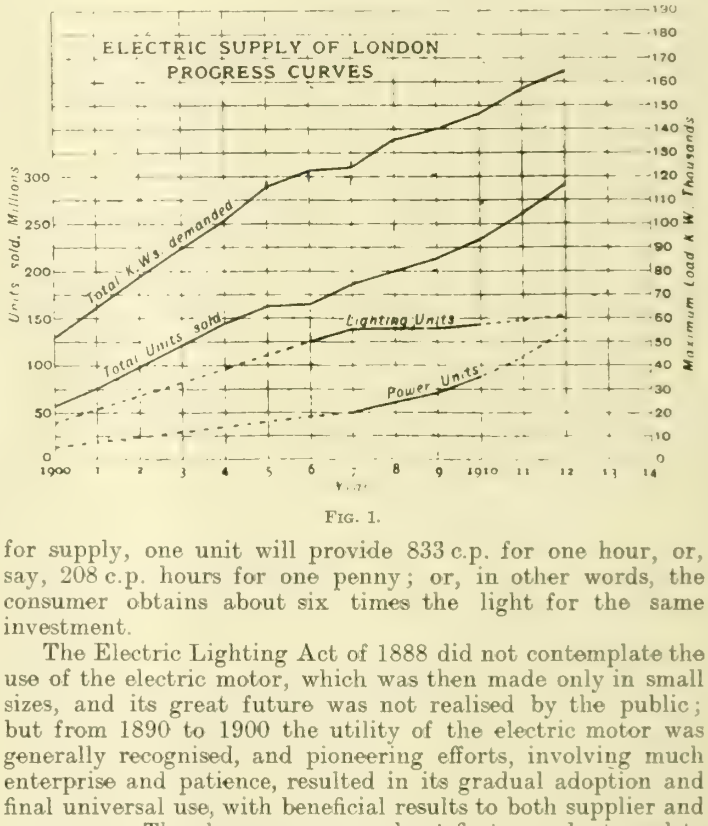


FIG. 1.

for supply, one unit will provide 833 c.p. for one hour, or, say, 208 c.p. hours for one penny; or, in other words, the consumer obtains about six times the light for the same investment.

The Electric Lighting Act of 1888 did not contemplate the use of the electric motor, which was then made only in small sizes, and its great future was not realised by the public; but from 1890 to 1900 the utility of the electric motor was generally recognised, and pioneering efforts, involving much enterprise and patience, resulted in its gradual adoption and final universal use, with beneficial results to both supplier and consumer. The slow progress made at first may be traced to the reluctance of power users to abandon expensive steam plants which were not worn out, and which were frequently of recent design. When these plants gave trouble, or required repair or extension, the user was tempted to try a small electric motor as an experiment—for each user evidently felt he was a pioneer—and the result was so convincing that not only have steam and other plants been removed, but a greater amount of power has been substituted.

The electric supply authorities in 1906 combined to make an exhaustive canvass of all factory power users in London, and ascertained that the total amount of power required in all districts within the County of London was 208,806 h.p., or, say, 156,600 kw. The total connection for electrical power now amounts to about 135,000 kw., or 86 per cent. of all power required, and the increasing use of this power is shown on the curve.

Before dealing more in detail with the use of power, it may be interesting to refer briefly to the steam plant employed by supply authorities. From 1886 to 1900 the Willans engine was remarkable for the perfection of its design and the skill shown in its manufacture. These engines occupied little space for the amount of power they produced, and, considering the high speed of the reciprocating parts, it is surprising that they were so reliable and cost so little in repairs. The demand for generators of larger size placed the Willans engine at some disadvantage, and after the year 1900 the steam turbine took command of the field. The remarkable economy of the steam turbine compelled many users to replace their Willans and other engines, securing not only more power for the same floor space, but also any amount of power from 500 kw. upwards.

The history of the steam turbine in this country is practically a biography of the life of the Hon. Sir Charles Parsons. The first Parsons turbine was constructed in 1881, and can now be seen in the South Kensington Museum. In 1888 a turbine generator, giving an output of 75 kw., was considered an achievement, and the steam consumption of 58lbs. per kilowatt-hour was considered most satisfactory. In 1893 a Parsons turbo-alternator of 350 kw., then considered an enormous size, was constructed under exceptional circumstances, requiring quick manufacture and successful performance. A number of these machines were ordered to enable me to overcome complaints of vibration arising out of the working of reciprocating engines, and it became necessary to replace the latter by steam turbines or to close the works. The result was successful; and while I must express the deepest gratitude to the inventor of the Parsons turbine, it is probable that the success of these machines encouraged the building of larger sizes and placed the turbine in the list of practical methods of electrical generation.

Five-hundred-kilowatt turbines followed in 1895, and the celebrated Elberfeld machines—constructed in 1900, and giving 1,000 kw. at a steam consumption of 19lbs. per kilowatt-hour—finally removed all doubts as to the glorious future of the steam turbine in this country. Machines to generate 5,000 kw. followed in 1903, and in 1913 we find that Messrs. Parsons are constructing a 20,000 kw. turbo-alternator for Chicago. An interesting development is now being applied to the Parsons turbine in the form of speed-reducing gear, consisting of the employment of toothed gear wheels running in oil.

The efficiency of the steam turbine is encouraging the attention of many expert investigators, and it is not surprising that Dr. Ferranti—the pioneer of electrical transmission and high-pressure generation — should have devoted his energies and inventive genius to applying a high degree of superheat to the steam used in a turbine, and to the necessary means of enabling the turbine to utilise it safely. The results so far obtained justify the expectation that a steam consumption of 8·5lbs. per kilowatt-hour can be obtained.

The necessity to use superheated steam must now draw our attention to the steam boiler. Prior to 1888 the steam boilers used in this country were of the cylindrical type, and the water-tube boiler came to us from America, with the usual prejudice to overcome, as high steam pressures had not hitherto been used, and the best points of the water-tube boiler were therefore not appreciated. This prejudice was, however, soon overcome. Among the advantages of the water-tube boiler are the small space occupied for the output; quick response to demand for steam; low capital cost; and efficiency in operation. There is also the advantage that renewals of any part can be carried out without affecting the remainder of the boiler, and therefore a boiler can remain young indefinitely; and, if properly maintained, the rate of depreciation depends solely on obsoletion, which, owing to the perfection of detail, is not likely to occur.

One effect of the great improvements in steam generating plant is that the 257 million units sold in 1911, together with the units expended in distribution and for works purposes, were obtained by the consumption of about 570,000 tons of coal. If the present use of electrical energy were replaced by the old method of a separate steam plant for each power user the amount of coal required would be at least 1,000,000 tons per annum more than at present, and the wasteful consumption of this increased quantity of coal would result in a repetition of the dense fogs which were so prevalent before the introduction of electrical supply. It must also be remembered that the distribution of power by means of underground mains has removed from the surface of the streets a large number of coal carts which formerly supplied the needs of power users, and also the necessary dust carts to remove the ashes.

It has been suggested that large electric power works in the coalfields or down the river would, by superseding all the existing generating works, secure some economy in the costs of generation. Such economies can easily be shown on paper, and it can with equal ease be demonstrated that the additional cost of mains and losses in transmission more than counterbalance any hypothetical economy in generation.

London is at present supplied from 38 generating works. Many of the works are equipped with plant of the latest design and best economy, and, having facilities for extension at low capital cost, it would appear to be wiser to convey coal to them rather than to provide expensive copper mains from distant works. Some of the existing works have sites of the utmost value to the future supply of London, and, so long as the centre of gravity of the whole demand falls at a hypothetical point not far from the south side of Blackfriars Bridge, it is clear there is greater economy in developing works on all sides of this point rather than the concentration of the load in a distant region. All the existing works have still some useful life left in them, and by a comparatively small expenditure they can be maintained in a high state of efficiency; but many of them are limited in their ultimate resources, and when they have exhausted the utility of the present plant it may be better to concentrate development on more advantageous sites.

The distribution of electrical energy involves problems which are not appreciated by the general public, and without entering into any technical details it may be said that the system of mains, including design, material, and workmanship, adopted throughout London is one of the most perfect examples to be found in any city, although it is not the cheapest. Lead-covered cables, insulated with oil-impregnated paper, and with the segments or strands of the copper conductor neatly and tightly laid together, are generally employed, and these cables—of which there is now more than 20 years' experience—actually improve with age; so long as the lead covering remains undamaged there appears to be no limit to the useful life of the cable. Dr. Ferranti was the first advocate and maker of this type of cable in the form of concentric conductors, and thus earned the title of the pioneer of electrical transmission.

The use of electrical supply in our homes has become a necessity of modern civilisation. The brilliance of the tungsten lamp, accompanied by the low cost of obtaining increased candle-power, has raised the standard of domestic illumination, and created a demand for more light. An electrical supply is now essential to secure the greatest convenience in carrying out the ordinary domestic work of the home. Vacuum cleaners, of all sizes and many designs, remove dust before it has time to accumulate, thus avoiding the necessity of flicking about with the housemaid's duster; the electric iron is quickly heated, and remains at a safe temperature without getting dirty; electric cooking stoves relieve anxiety; electric motors drive the sewing machine, boot cleaner, coffee grinder, and other kitchen plant; and electric cigar lighters can be placed all over the house.

Electric radiators, chiefly of the luminous type, have brought comfort and peace into many offices in the City of London, banishing coal, and avoiding the annoyance and dust caused by the removal of ashes. Electric heaters for use or storage of hot water require some explanation, for they are of two distinct types; in one type water can be heated instantly simply by pouring it through an electric geyser, in this case the meter recording the larger amount of energy taken in a short time, and by using a heater of the cumulative type a very small amount of energy is taken over a longer period. Electric ozonisers have proved their utility in purifying bad air and water. The ventilation of our public buildings, especially the Houses of Parliament and Law Courts, is frequently the subject of complaint, and it seems strange that those who make our laws, and those who interpret them, do not legislate for the provision of invigorating air, and give electrical supply the opportunity of introducing the equivalent of thunderstorms—but without

the thunder—and pine woods. At present the health of the workers in our factories receives more attention than that of our national representatives and judges.

The electric vehicle may also become more generally used in this country when the petrol motor-car retires on account of high price or famine in petrol. We have seen how the supply authorities have successfully pioneered the application of electric power, and the increasing use of the electric motor for all trades and purposes is a convincing proof of the advantages which have been demonstrated. The details given in Table II., taken from individual typical examples, may be interesting:—

TABLE II.

Trade.	Kws. connected.	Cost of supply per annum.			Trade.	Kws. connected.	Cost of supply per annum.		
		£	s.	d.			£	s.	d.
Printing (newspaper)	1,036	1,812	2	6	Confectioners	174	569	11	9
Printing (general)	56	119	7	11	Rubber factory	222	219	16	5
Box makers ..	9	80	0	10	Saw mill	79	302	8	2
Chemists	92	221	11	4	Spice factory	69	371	4	4
Brewers	39	153	10	6	Cabinet maker	87	302	15	2
Paint factory ..	108	253	2	11	Ironfounders	150	877	14	2
Soap makers ..	110	68	16	9	Vinegar Brewery	15	201	14	10
Glass makers ..	18	118	16	0	Marble masons	101	294	2	0
Blouse makers	13	89	6	4	Tobacco manufacturers	22	138	3	5
Wood wool makers	166	623	8	6	Cold store ..	164	922	2	9
Packing-case makers	52	214	17	10	Flour mills....	51	158	15	11
Tailors	63	159	15	5	Ink mills	48	235	2	10
Biscuit factory	265	419	2	6					

The average cost for each kilowatt connected in the representative cases given in this table works out at £2. 15s. 8d. per annum, or per horse-power, say, £2. 1s. 6d. per annum. Had this horse-power been obtained from the old-fashioned engine, with the losses in shafting, belting, and steam pipes, starting up the plant and keeping the boilers warm all night, and the additional labour required, the cost would have been from £6 to £8 per annum, with further costs for continual repairs and all the annoyance of running steam plant taking up more room than it was worth. For driving printing machines—especially the Double Supplement type of press, taking about 25 h.p., the Sextuple Press, taking 48 h.p., and the Double Octuple Press, taking about 108 h.p.—the use of the electric motor has many exceptional advantages. Mr. G. W. Mascord, the Mechanical Superintendent of United Newspapers, Ltd., has perfected ingenious arrangements for securing absolute control of the speed of these printing presses, and in starting the plant or in running slowly this control is of great advantage. Mr. Mascord has carefully worked out the cost of printing newspapers, and finds that an area of 88,000,000 sq. in. of actual printed matter costs one shilling. This area is equivalent to 14 acres.

We now come to the important question of street lighting. The development and perfection of the motor vehicle has resulted in an increased speed of street traffic, with many advantages, though with some danger. To maintain safely this increased speed during hours of darkness a higher standard of artificial illumination has become necessary. A motor vehicle approaching at a speed of 20 miles an hour covers nearly 10 yards in one second, and, travelling without noise, leaves only the power of vision to protect the pedestrian. The adequate illumination of all thoroughfares will reduce the necessity of each vehicle carrying a search light and side lights, or practically forming a travelling lighthouse. The electric lighting of Cheapside is, like many of the main thoroughfares in the City of London, carried out by flame arc lamps, centrally suspended from steel ropes stretched across the street and placed at a considerable elevation in order to secure freedom from shadow and glare. Improved street lighting is receiving consideration by the various borough councils in London.

The statutory conditions under which the electric supply authorities accepted their obligations require some explanation, as the Act of 1888, which remedied the defect in the Act of 1882, has received some amendment by the Acts of 1908 and 1910, so far as London is concerned, and an Act of 1909 removed some difficulties and gave increased facilities. The London County Council now possess powers of purchase of the company undertakings in 1931, and after that date at recurring periods of 10 years, with the exception of the City of London, where the Corporation have a prior right which expires in 1914. The terms of purchase are "the then value of all lands, buildings, works, materials, and plant, suitable to and used for the purposes of the undertaking, provided that the value of such lands, buildings, works, materials, and plant shall be deemed to be their fair market value at the time of the purchase, due regard being had to the nature and then condition of such buildings, works, materials, and plant, and to the state of repair thereof, and to the circumstance that they are in such a position as to be ready for immediate working, and the suitability of the same to the purposes of the undertaking . . . but without any addition in respect of compulsory purchase or of goodwill." These terms were practically based on Section 43 of the Tramways Act, 1870, and evidently provide for a fair market price for an undertaking in working order. The recent award in the arbitration proceedings to ascertain the sum to be paid by the Post Office for the acquisition of the National Telephone Company may therefore be referred to with some interest, particularly as the terms of purchase were on the same lines, though with variations much in favour of the electrical supply undertakings. The Telephone Company claimed £18,325,435, were awarded £12,515,264 (subject to certain adjustments which are at the moment *sub judice*), and had provided reserve funds which reduced their capital expenditure to £12,473,627.

The total capital expended by all the companies up to the end of 1912 will be found in Table III., under the various items which appear in the standard form of accounts. It should be noted that the Willesden works of the Metropolitan Electric Supply Company, being outside the boundary of the County of London, are not subject to purchase by the London County Council under the terms as quoted above, but may

TABLE III.—*Summary of Total Capital Expenditure of all Electric Supply Companies in London*, 1912.

Description.	Amount expended, Dec. 31, 1912.	Description.	Amount expended, Dec. 31, 1912.
Land and buildings ..	£3,162,555	Brought forward ..	£13,869,433
Plant and machinery ..	3,935,310	Public lighting	65,827
Tools and appliances ..	40,124	Station fittings, &c. ..	28,195
Accumulators	123,908	Offices & furniture, &c.	42,423
Transformers	529,531	Distributing stations..	113,607
Mains	5,349,304	Wells (artesian)	6,530
Meters, instrum'ts, &c.	625,427	Preliminary expenses	487,181
Motors, &c., on hire ..	93,274		
Carried forward ..	£13,869,433		£14,613,196

be purchased by agreement. The Bow works of the Charing Cross and City Company are also subject to purchase under special conditions. If we consider that money has to be found by the companies to provide for the necessary capital outlay required to develop further such an important industry, and that the Act of 1908 authorises the London County Council to advance money only for three years prior to 1931, it will be seen that for the next 15 years the interests of shareholders will require close attention, and that works of development will require strict economy, coupled with immediate return of some profit, to avoid a loss of capital to those who have encouraged and practically founded a new industry.

The average price in London for the year 1910, given in the statistics issued by the London County Council, was 3·42d. per unit for lighting and 1·16 pence for power, or a general average of 2·54d. per unit, including meter rents.

Crane Accident at a Colliery.—An accident occurred on the 2nd inst. at Dechmont Colliery, Cambuslang. A number of miners were waiting in the vicinity of the pithead, when suddenly the jib of a large crane used for loading purposes crashed to the ground. A number of the men had narrow escapes, and two were seriously injured.

APPARATUS FOR DISCHARGING CONDENSED WATER.

THE accompanying illustrations show an arrangement of apparatus for discharging condensed water from condensers, the invention of Mr. D. B. Morison, Hartlepool Engine Works, Hartlepool, and The Contraflo Condenser and Kinetic Air Pump Company, Ltd., of 62, New Broad Street, London, E.C. In this arrangement two pumps arranged in series are employed for discharging water of condensation from a steam condenser under vacuum, the pump which is connected directly to the condenser and discharges water to the second pump being, for distinction, referred to as the head pump, and the second pump being, for a like reason, referred to as the pressure pump. The first pump discharges directly into

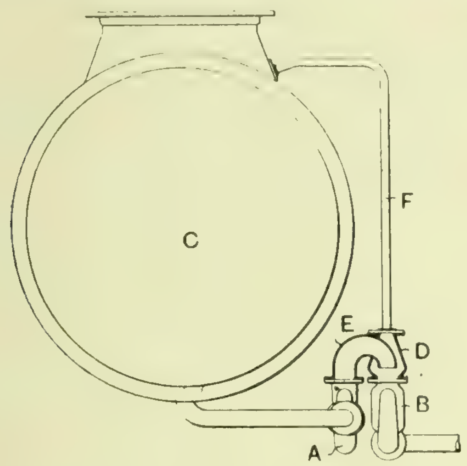


FIG. 1—APPARATUS FOR DISCHARGING CONDENSED WATER.

the second pump, the casing of the second pump being closely connected with the receiver into which the first pump discharges, the receiver being provided with an internal nozzle or plate, and so arranged as to produce a relatively large surface area for the liberation of air bubbles, which rise to the surface of the water and escape through a pipe or conduit to the condenser or to evacuating means.

Figs. 1 and 2 show forms of apparatus, and Fig. 3 a section on the lines S—S of Fig. 2. In Fig. 1, in which the water of condensation is withdrawn from the condenser C by the head pump A and discharged by the pressure pump B, the discharge from the first pump and the suction of the second pump are connected to an air liberating receiver D, which contains a nozzle E that is arranged in the centre of the receiver with a free space around the circumference of its discharge, so as to facilitate the liberation of air bubbles from the water discharged from the nozzle, whereby the air is thus enabled to rise upwardly from all sides and escape freely, the top of the receiver having connected to it a pipe F, which communicates with the condenser C into which the free air passes. The nozzle E may be arranged, as shown, so that the water issuing therefrom will be delivered in the direction of and into the suction inlet of the pressure pump B, whereby the kinetic energy of such water can be utilised to assist its flow into the pressure pump. In Figs. 2 and 3 the head pump A, the pressure pump B, and the air liberating receiver D are contained in the same casing, the discharge from the head pump A being guided upwardly by the plate G towards the top of the receiver D, where it passes over the plate in the form of a stream having a relatively large width but small depth, so that the air bubbles in the water can readily rise to the surface and escape through the pipe F into the condenser.

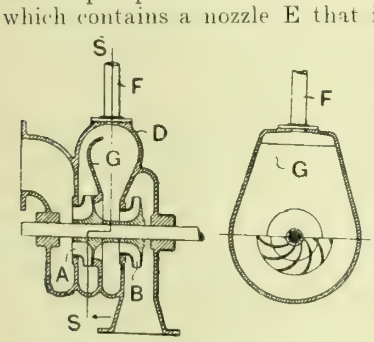


FIG. 2. FIG. 3.
APPARATUS FOR DISCHARGING CONDENSED WATER.

In the arrangements described, the pipe F may be of larger diameter than shown, and form a suitable receiver for such a quantity of water at such a head as may sometimes be necessary in order to promote the satisfactory working of the pressure pump B. The pressure pump B may advantageously be connected to a multi-stage boiler feed pump, so that the water is delivered direct to the boilers in a condition of minimum aeration, or the pressure pump may first discharge into a feed heater, which may be elevated, and thence into a multi-stage feed pump under float control.

THE POWER STATION OF THE CITY OF LONDON ELECTRIC LIGHTING COMPANY, SOUTHWARK.

ON Saturday, May 3rd, a visit was paid by members of the Institute of Marine Engineers to the power station of the City of London Electric Lighting Company, Ltd., Bankside, S.E. The main engine room, which was first visited, is a building 520ft. long by 50ft. wide, with a gallery containing switch gear, meters, and controlling gear of various descriptions extending the length of the room on either side. The total capacity of the plant is about 26,000 kw., or about 42,000 i.h.p., about one-third of the electricity generated being high tension, alternating current, with a periodicity of 100 per second, supplied to transformer stations; the other two-thirds is for the supply of continuous current. The oldest type of machinery remaining in the works is the Ferranti alternating-current generator, of which there are two sets, each of 2,500 i.h.p., giving 1,500 kw., but these are not now used, and will shortly be scrapped. The engines are compound of the inverted vertical type, with two cylinders of 38in. and 68in. diam. and 30in. stroke, one on either side of the alternator armature. The engines run at 150 revs. per minute, the steam pressure being 160lbs.

The latest additions to the plant are three Parsons high-speed turbo-alternators, single-phase, each of 3,000 kw., the revolutions being 1,500 per minute. For the generation of continuous current a similar turbine of 2,500 kw. capacity has been installed, and, in addition, there are six Musgrave Westinghouse slow-speed 2,000 kw. generating sets, and three Allis Chalmers-Westinghouse 1,000 kw. sets. The Musgrave engines are of 4,000 i.h.p., the cylinder diameters being 38½in. and 76in. by 54in. stroke, running at 75 revs. per minute, and the Allis Chalmers engines are of 2,000 i.h.p., the cylinders being 26in. and 60in. diam. by 48in. stroke, running at 90 revs. per minute. The Westinghouse generators are multipolar, the armatures being provided with compensating windings.

In the boiler house, which was next visited, there are 46 Babcock & Wilcox boilers of the land type and 12 Fraser dry back marine type. Each of the Babcock boilers has a heating surface of 4,400 sq. ft., and is composed of 20 sections, each consisting of 19 solid drawn mild steel tubes 3in. diam. by 15ft. long. There are two steam and water drums, each 48in. diam. by 21ft. long, made of steel plates ½in. thick. These drums are surmounted by a cross drum 24in. diam. by 8ft. long, provided with a steam nozzle of 7in. diam. Most of the boilers are fitted with mechanical stokers, and induced draught is used. A main flue receives the waste gases, which pass through fuel economisers situated at the end of the flue.

The river frontage provides a convenient and economical means of obtaining the necessary coal supply, the coal afterwards being transported from the wharf bunker to the store above the boiler-house, which has a capacity of about 10,000 tons, and from which the coal is conveyed to the automatic stokers through chutes. The ashes and clinker are similarly conveyed to the wharf or roadway, whence they may be removed at once into barges or carts. Another advantage of the proximity to the river is that the water for condensing purposes can be easily obtained. For this purpose three sets of Allen's steam-driven and two sets of motor-driven centrifugal pumps are installed, the maximum lift at lowest tide being nearly 20ft.

Through the courtesy of Mr. Frank Bailey, chief engineer to the company, a large number of members of the Institute were privileged to make this interesting visit.

ROLLING-MILL PRACTICE IN THE UNITED STATES.*

BY J. PUPPE, D.ING.

SECTION MILLS (Table I.).

STRUCTURAL iron is a product which as far as its economical importance and technical character are concerned is comparable with rails, but the development of the manufacture of wrought iron or mild steel structural shapes is comparatively recent. The first wrought-iron bridge was built by Andrew Thompson in 1832 for the Pollock and Govan Railway, near Glasgow. It had a span of 31ft. 6in., and consisted only of flats and bars. Zores, at Paris, was the first engineer who introduced wrought-iron I-beams, the first beam of that section, measuring 5½in. deep and 17ft. 9in. long, having been rolled in 1849. The first angles and the first T-shapes rolled in Germany were rolled at the Rasselstein Works in the years 1831 and 1839 respectively. The first I-beam was made at the Phœnix Works in 1857, and the first Z-bar at Burbach in 1862.

About the same period, in 1854, the Trenton Iron Company, in the United States, began rolling girders of 7in. depth, weighing about 81lbs. per yard, which were shaped like the cast-iron girders formerly designed by Hodgkinson (similar to the deck-beams or bulb sections of the present day). They were rolled in a mill with three vertical rolls patented by William Burrows, which was afterwards reconstructed as an ordinary 3-high mill and was used for rolling I-girders. Long before that, however, in 1819, Samuel Leonard had rolled angles at the Union Rolling Mill, Pittsburg.

The necessity for standardising sections of structural material was first recognised in Germany, the makers being urged thereto on account of the great variety of sections specified, which enormously increased the cost of rolling. The Verein für Eisenhüttenwesen (Society of Ironworkers) took the matter up, and in December, 1876, they brought out the first book of standard sections, which in 1884 was also adopted by Carnegie Brothers & Co. in the United States, with such alterations as were necessary in the 12in. and 15in. girders. The new steel sections were 20 per cent. lighter than the corresponding iron sections. Unification was hastened by the disappearance of iron girders from the market, which enabled sections to be omitted which differed from others only by a few pounds per yard in weight. In 1895 the American Steel Manufacturers' Association began the work of standardising sections in America. In Great Britain the standardising of I-beams was completed in 1903, the sections adopted being in general the same as those of the United States, except that in girders over 15in. deep the flanges were slightly wider and the webs thicker, the weights consequently being rather greater. In 1885 the Darlington Iron and Steel Company first rolled wide-flanged beams, approximating to H-beams, and the actual H-beam of to-day appeared first in 1900 in a section book of the Phœnix Iron Company. Since 1907 H-beams have been regularly sold by the Carnegie Steel Company. In 1902 wide-flanged girders began to be regularly rolled in the Grey Mill at Differdingen, and in 1907 at Bethlehem under the same patent. But before the earlier date wide-flanged girders up to 10in. depth were rolled in Germany in ordinary grooved rolls.

As the constructive development of steel sections advanced, their economic importance in the American steel industry rapidly increased, necessitating special arrangements for their production on a large scale as in the case of rails, though not to such a degree, owing to the large number of different sections which are required. For the same reason open-hearth steel can more easily be used, as it is not required to roll material in such large quantities as are provided by the Bessemer process. Moreover, open-hearth steel is preferred for structural work of all kinds. In 1890 the production of Bessemer steel structural material was 85,440 tons, as compared with 68,123 tons of open-hearth steel material, and in 1900 the output of structural material from Bessemer steel amounted to 263,800 tons, whereas that from open-hearth steel had risen to 566,092 tons.

* Paper presented at the annual meeting of the Iron and Steel Institute, May, 1913.

As in the case of rails, the ever-increasing demand for structural steel led to the design and construction of special mills, although in consequence of the greater number of sections and difference in their sizes, involving great differences in the size of the initial section, it has not been possible to standardise the rolling operations to the same extent as with rails. The cogging rolls of section mills are used in a manner conforming much more to European practice than is the case with the cogging rolls working in combination with rail rolling mills, which can be divided into separate stands on account of the almost uniform size of the initial section for the finishing mill.

The practice in rolling I-girders differs essentially from German practice in that the preliminary shaping of the ingot is carried much further in the cogging mill, or in a universal slabbing mill, as at the Lackawanna Steel Company's works, so that the finishing operation is very much simplified. For this preliminary shaping a great number of passes are made. For instance, it was noted that in roughing down an ingot for a 15in. girder 37 passes were required which were made in about six minutes (Fig. 1). It is clear that by upsiding in the groove a considerable number of rough shapes

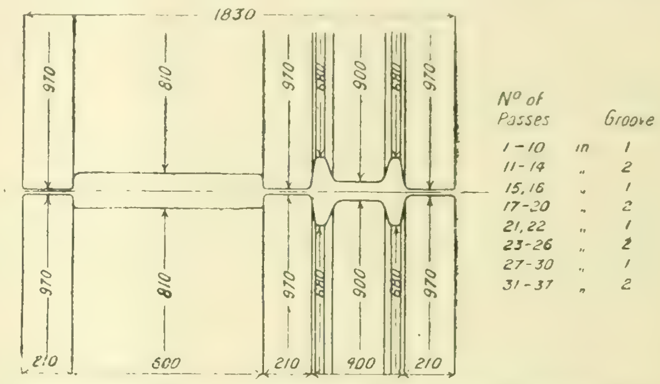


FIG. 1—ROUGHING ROLLS FOR I-GIRDERS. LACKAWANNA STEEL COMPANY.

can be obtained with comparatively few grooves, and that by using heavier ingots the production will be correspondingly increased. At Lackawanna the weight of the ingot was about 6 tons. After roughing down the ingot was cut into three lengths of about 16ft. each. The rough section measured about 15in. deep, width of flange 12in., thickness of flange 1¼in. to 1½in., and thickness of web 2¾in., so that eight passes in the finishing mill were sufficient to finish a 15in. girder. All girders over 9in. deep are roughed out in the cogging mill in this manner at that company's works, and, according to the views of the men in charge of the rolling mill, the method has proved quite satisfactory. In Germany, however, the standard girders never receive their preliminary shaping in the cogging rolls, the section being formed entirely in the finishing mill. Only in the universal mills of Grey, and of Sack and Puppe, is it necessary for the ingot to be shaped out roughly in the cogging rolls first.

The type of mill for rolling structural steel is the 3-high mill which was first used by John Fritz in 1857 at the works of the Cambria Iron Company for rails and structural iron, and represents the standard type of rolling mill for this class of work. Two-high mills are of course also used where the plan of sub-dividing the mill into several trains has been adopted. The diameter and length of roll of these mills show that these dimensions are influenced by the nature of the work to be performed. In many instances the roll diameter is considerably less than is usual in German practice. As the diameter is chiefly determined by the size of the I-beams and U-sections, the smaller diameters usual in American practice are no doubt possible owing to the preliminary shaping which the girders receive in the cogging rolls and the consequent small number of passes in the finishing mill. This varies considerably of course, and depends upon the size of the initial and the final sections, the aim being to ensure steady working by not allowing too long pauses to occur in one or another stand of rolls, assuming that the supply of ingots or billets is not sufficient to allow the cogging and finishing mills to work independently. That would always be the case where, as at Jones & Laughlin's works, the cogging mill has to supply besides a continuous billet mill with material. Nevertheless, the number of passes

varies between one and five in the first trio alone, and the mill is so arranged that only two passes are given in the following stand and one in the finishing rolls.

In a single instance, that of the section mill No. 2 of the Illinois Steel Company, one of the newest installations, the number of passes is definitely fixed, and is dependent upon the arrangement of the stands, as in rail rolling mills. Such an arrangement demands a cogging mill which supplies material of the required rough section; in this instance a 35in. 2-high reversing mill is installed which supplies this section mill alone.

Whereas in Germany at the present time two rolling mills for special girders have been installed, one at Differdingen and one at Rombach, in the United States there is only one such mill, of the Grey type, at Bethlehem, in which 30in. girders with 15in. flanges have lately been rolled. It is noteworthy that the slope of the inner side of the flange, which in Germany amounts to 9 per cent., has been reduced to 2 per cent. at Bethlehem, so that the faces of the flange are practically parallel. The mill being of the standard Grey type, with very little bevel on the ends of the horizontal rollers, the friction on the inside face of the flange is very great and the differences in the surface speed are also considerable, both of which factors unfavourably affect the quality of the finished girder, as has been shown by tests recently carried out by an independent authority.

With regard to construction, the Grey rolling mill at Bethlehem differs chiefly from that at Differdingen in that in the latter mill the billet is first rough shaped in a cogging mill and is finished in a single stand of the Grey type, whereas at Bethlehem two Grey mills are installed for the purpose of increasing the output and of giving a slope of 2 per cent. to the inner faces of the flange. A few constructional improvements have been made in the Grey mills at Bethlehem, but otherwise they are built on exactly the same principle as the one at Differdingen. The number of passes varies between 17 and 25 in the first stand and between 5 and 7 in the second, according to the final shape of the section. In the case of heavy girders with especially wide flanges and a short web, only one pass is made in the second rolls. For roughing out the section in the cogging rolls as many as 27 passes are made. The maximum output in 12 hours, using 8 ton ingots, is given as 800 tons. Noteworthy also are the straightening presses, in which the finished girders are straightened in their horizontal position immediately after leaving the rolls. The distance between the two Grey mills is 303ft. The hot beds upon which the girders are laid are of specially strong construction, in order to prevent the bending of heavy sections.

TABLE I.—*Section Mills.*

No.	Name of Company.	Type.	No. of Stands.	Particulars of Drive. Type of Engine.	No. of Engine.	Dimensions (Cycles and mm.).	Revolutions.	Capacity.	Roll Diameter (mm.).	Initial Section.	No. of Passes.	Production.
1	Lackawanna Steel Co., Section Mill No. 2.	Trio	3	Flywheel steam-engine	1 1	1118 × 1676 1118 × 1289	—	—	610	—	—	140,000 tons yearly.
2	Carnegie Steel Co., Homestead.	Trio Trio	2 2	Flywheel steam-engine	1 1	— —	— —	— —	840 650	—	—	1,600 tons daily.
3	Carnegie Steel Co., Homestead.	Trio	2 roughing 1 finishing	Flywheel steam-engine	1 1	— —	—	—	900	Rough-shaped material	Varies	16,000–20,000 tons monthly.
4	Jones & Laughlin Steel Co.	Trio Trio	2 2	Tandem Corliss compound direct coupled	1 1	1070/1880 × 1375 965/1680 × 1220	60–110 80–90	Steam pressure 155lbs.	660 1680	Various sizes	6–10	Varies
5	Bethlehem Steel Co.	Trio	3	Twin tandem compound	1	813/1421 × 1370	—	—	715	—	—	400 tons in 10 hours.
6	"Grey" Rolling-mill	Duo cogging universal finishing mill	1 2	Twin tandem compound reversing	1 2	1010/1670 × 1370 1010/1670 × 1370	Geared 3 : 5 direct coupled		1170	Weight of ingot 7.7–8.2 tons	I. 17–25 II. 5–7	800–1,000 tons daily
7	Illinois Steel Co., Section Mill No. 1.	Duo reversing Trio Duo	1 2 1	Twin tandem compound reversing	1 1	914/1574 × 1321 914/1574 × 1321	150 max.	Each 4500 h.p.	813 dia. × 1980 710 dia. × 1676	12in. × 15in down to 4in. × 4in.	—	168,000 tons yearly
8	Illinois Steel Co., Section Mill No. 2, attached to duo reversing cogging mill, 35½ inches diameter.	Duo Trio Duo Duo	4 2 1 1	Alternating current induction motors	1 1	2200 volts 25 cycles 25 cycles	91	3000 h.p. — 1000 h.p.	600 dia. × 1115 610/533 dia. × 1200 533 dia. × 915	—	4 4 1 1	12,000 tons monthly

MERCHANT MILLS (Table II.)

The economic advantages which apply to section mills and the supply of structural steel apply also to the manufacture of merchant sizes, but the product being much lighter, the mills for rolling it differ from the ordinary section mills in arrangement and construction. Here also the great demand for merchant sizes has led to the concentration of merchant mills in large works, so as to facilitate manufacture on a large scale, the conditions for which are very much favoured by the practice of giving large orders for material in comparatively few sections, which again can be allotted by the Steel Corporation to certain works, each especially equipped for dealing with a few particular classes of product. Under these unusually favourable conditions a type of plant has been developed for turning out large quantities of light sections, though such plant, if it had to work under European conditions, could not possibly be run at a profit.

The dividing up of the stands into separate trains depends upon the facility for bringing back the bar. If this is not practicable, a duo is used in conjunction with a trio, the latter being provided with the object of doing work on the bar during its return. The arrangement is then similar to that adopted at various rail mills, and at No. 2 section mill at the Illinois Works; the three merchant mills at Gary (Nos. 8, 9, and 10, Table II.), and the cross-country mill at Ohio

(No. 5, Table II.) are laid out on that plan, and work with remarkably good results, the cross-country mill, in particular, giving very large outputs of comparatively small sections.

The hoop iron mill for cotton ties (No. 6, Table II.) at Ohio is specially noteworthy, on account of the fact that only one section is rolled, and, notwithstanding the very small dimensions of the hoop iron, a very large output is obtained. This result is due to the ability to work at a very high pressure, and to the fact that parts of the mill have, in a measure, become so adapted to the one section that breakdowns are almost unknown, thus proving how very favourably the capacity and the economy of a rolling-mill are affected by sub-division, and by keeping to one class of work only. An ordinary efficient high-speed or merchant mill working on a number of sizes of hoop iron, but otherwise under the same conditions, would scarcely produce 30 tons per day on an average. The specialisation of rolling-mills cannot be carried to the same point under European conditions, which only admit of a limited sub-division, by reserving some mills for round and square iron, others for flats and hoop iron, and others again for sections. In the Ohio Works and the Union Works there are altogether 23 merchant mills, which makes it possible for each mill to run on a class of product which varies as little as possible in size.

The diameter of the merchant mills for the smallest sections is usually 10in., increasing to 18in. for larger sections. Comparatively large sections are rolled in the 18in. mills, and, in view of the short length of the body of the roll, the choice of size appears to be quite justified. In an ordinary trio an intermediate mill with 24in. rolls would be required for these sections.

(*To be continued.*)

TABLE II.—*Small Section Mills.*

No.	Name of Company.	Type.	No. of Stands.	Particulars of Drive. Type of Engine.	No. of Engine.	Dimensions (Cycles and mm.).	Revolutions.	Capacity	Roll Diameter (mm.).	Initial Section of Ingot or Billet.	No. of Passes.	Output.
1	Lackawanna Steel Co., Merchant Mill No. 6	Trio Trio Duo	3 4 2	Horizontal Vertical Engine	1	712/1270 × 1219	—	1400	406 305 203	6in. × 6in. Max. length =9ft.	Varies	75,000 tons yearly.
2	Lackawanna Steel Co., Merchant Mill No. 9	Continuous	6 2	Tandem Corliss Compound Corliss	1 1	— —	— —	— —	305 254	1¾in., 2in., or 2½in. dia.	14 max.	10,000–12,000 tons monthly
3	Carnegie Steel Co. (Duquesne).	Duo Half continuous	4 Continuous 6	Tandem Compound	1	762 1372 × 1219	—	—	330	—	10 max.	700 tons daily (?)
4	Carnegie Steel Co. (Duquesne).	Duo Half continuous	4 Continuous 6	Tandem Compound	1	762 1372 × 1219	—	—	—	—	10 max.	480 tons daily (?)
5	Carnegie Steel Co. (Ohio), Union Works, "Cross Country Mill"	Half continuous	6 duo 1 trio	—	1		—	1500	254	1½in. × 1½in. up to 3½in. × 3½in.	8	500 tons daily of the heavier sections
6	Carnegie Steel Co. (Ohio), Union Works, "Cotton tie Mill."	Continuous	9	—	—	—	—	—	254	1½in. × 1½in.	9 (Reduction 36%)	80 tons in 12 hours
7	Jones & Laughlin Steel Co.	Half continuous	5 Continuous 6; stepped rolls	Direct Coupled Belt Drive	1 1	— —	— —	900 900	310 310	4in. × 4in. —	6–11 —	Average: 175 tons to 230 tons
8	Indiana Steel Co. (Gary).	Half continuous	5 duo 2 trio	A.C. Induction Motors	1 (stands 1–6) 1 (stand 7)		91 182	3200 650	} 450	Up to 6in. × 6in.	9	14,000 tons daily
9	Indiana Steel Co. (Gary).	Half continuous	5 duo 2 trio	A.C. Induction Motors	1 (stands 1–6) 1 (stand 7)		91 182	3200 650	} 350	—	9	11,000 tons monthly
10	Indiana Steel Co. (Gary).	Half continuous	5 Continuous 1 trio 1 trio 1 duo	A.C. Induction Motors	1 (stands 1–5, 7) 1 (stands 6 & 8)		112 182	2000 650	1–4 = 355 dia. 305	— —	10 —	9000 tons monthly —
11	Indiana Steel Co. (Gary).	Half continuous	5 Continuous 4; stepped rolls	A.C. Induction Motors	1	6600 volt	92 or 113	2500	355 300	2in. × 2in. up to 4in. × 4in.	9	9000 tons monthly
12	Indiana Steel Co. (Gary).	Half continuous	6 Continuous 3 (2 with stepped rolls)	A.C. Induction Motors	1	6600 volt	133–162	2000	254	2in. × 2in. or 3in. × 3in.	12	7000 tons monthly

Institution of Civil Engineers: Awards.—The Council of the Institution of Civil Engineers have made the following awards for papers read and discussed during the session 1912-1913: A Telford gold medal to Mr. Murdoch Macdonald, C.M.G. (Cairo); a George Stephenson gold medal to Mr. G. D. Snyder (New York); a Watt gold medal to Mr. H. A. Humphrey (London); Telford premiums to Messrs. C. W. Methven (Durban), B. Hall Blyth, jun. (Edinburgh), C. J. Crofts (Durban), Frank Grove (Canton), B. T. B. Boothby (Hankow), and Francis Carnegie (Enfield Lock); and the Manby premium to Captain C. E. P. Sankey, R.E. (London).

INDUSTRIAL AND TRADE NOTES.

Tinplate Workers' Wages Agreement.—At the annual meeting, held on the 7th inst., of the South Wales Tinplate Conciliation Board, which regulates wages and conditions of 28,000 workers, a new wage agreement was amicably arranged for another year.

Brassworkers' Wages.—At the annual meeting of the National Society of Brassworkers and Metal Mechanics held at Birmingham on the 6th inst. it was decided that an application be made for an advance of ½d. per hour, and 10 per cent. on piece-work rates.

Scottish Ironmoulders' Wages.—The Associated Ironmoulders of Scotland have notified the Scottish Federation of Iron and Steel Founders of their desire for an increase in wages. The present minimum rate of wages, which has been in operation for six months, is 9¼d. per hour, and the claim now is for an advance of ½d. per hour to those employed on time rates and 2½ per cent. to those on piece work. The representatives of the men state that the question of wages has been receiving attention for some time, and that several districts have been pressing for an advance. The claim, it is understood, is to be submitted at the first meeting of the executive of the Employers' Federation. Three months' notice is required on either side before any alteration in the rates of wages can be considered.

Order for Vessels for the Portuguese Navy.—The Portuguese Government has, we understand, awarded the contract for the following vessels to the Portuguese Naval Construction Syndicate, which consists of an association of British shipbuilders composed of the firms of Messrs. John Brown & Co., Ltd., Cammell, Laird, and Co., Ltd., the Fairfield Shipbuilding and Engineering Company, Ltd., Palmers Shipbuilding and Iron Company, Ltd., J. I. Thornycroft & Co., and the Coventry Ordnance Works, Ltd. The Fiat San Georgio of Spezia is also associated with these firms: Two cruisers of about 2,500 tons, six destroyers of about 900 tons with a speed of 32 knots, three submarines of about 350 tons, one depôt ship for submarines of about 150 tons. The whole of these vessels are to be completed in two years, and the cost of this section of the programme amounts to about £1,500,000. The submarines will be built at Spezia.

Trade Circulars and Catalogues.—From Richard Melhuish, Ltd., 50, Fetter Lane, London, E.C., we have received a very comprehensive catalogue of mechanics' and machinists' requisites and small tools. There is scarcely a fitting or appliance of the small tool kind which is not included in this somewhat ponderous tome of nearly 600 pages.—Reinforced Metal, Ltd., 175, West George Street, Glasgow, an interesting memorandum describing the method of reinforced concrete construction by the Thomson patent owned by the company, along with a report on some tests of same by Prof. Gray, of the Glasgow University.—The British Prometheus Company, Ltd., Salop Street Works, Birmingham, an illustrated catalogue of their various electrical specialities for domestic heating purposes.—David Rowell & Co., 33, Old Queen Street, Westminster, a little catalogue relating to constructional iron work in the shape of roof principals for workshops, &c.—Petters, Ltd., Nautilus Works, Yeovil, particulars of their semi-Diesel crude oil engines, with particulars of some working tests.—The General Electric Company, Ltd., 67, Queen Victoria Street, London, E.C., a catalogue and price list of their various fittings in connection with their "Dalite" system of reflected ceiling lighting.

Confidential Information as to Openings Abroad for British Trade.—The arrangement inaugurated on January 1st, 1907, whereby the names of British firms desirous of receiving confidential information as to opportunities for the extension abroad of those branches of trade in which they are specially interested, and as to other connected matters, are placed on a special Register at the Commercial Intelligence Branch of the Board of Trade, has, according to the "Board of Trade Journal," met with widespread approval, as evidenced by the steady increase in the number of names so registered. Firms desirous of utilising this source of information are required to pay an annual fee of one guinea to the Accountant General, Board of Trade, Whitehall Gardens, London, S.W., for the service, including the supply of the "Board of Trade Journal." The confidential information which is communicated to firms upon the Register is received from His Majesty's Consular Officers in Foreign Countries, from His Majesty's Trade Commissioners, and the Imperial Trade Correspondents in the British Dominions, and from other sources available to the Commercial Intelligence Branch. It may be stated that confidential information thus received relates mainly to openings for British trade abroad, and is communicated to firms on the Register in circular letters. During 1912, 1,098 such circular letters were prepared, and copies (totalling 146,578) were dispatched to firms on the Register interested in the trades to which the circular letters respectively related, as compared with 1,091 circular letters and copies totalling 147,082 sent out in 1911.

Equipment Desired for the Hong Kong University.—H.M. Commercial Attaché at Shanghai, in a recent report, directs attention of makers of engineering appliances and machinery in the United Kingdom to the advantages afforded them by the University recently established at Hong Kong under the presidency of Sir Charles Eliot. The faculty of engineering provides instruction in civil, mechanical, and electrical engineering, to which it is hoped mining and metallurgy will be added later. As far as the first three are concerned the new University is already the best equipped institution in China, and it is thought that before long many of the Chinese engineering students will choose to complete their studies at this British school instead of going abroad. Firms in the United Kingdom would, he observes, secure a good and permanent advertisement by presenting machinery and equipment to the University. The value of the apparatus, &c., already presented by British firms amounts approximately to £5,000. The Heat Engine Laboratory is almost completely equipped, but a small steam turbine with condensing plant is needed, also a separate condensing plant, indicators, CO_2 recorders and calorimeters. One or two small refrigerating plants would also be acceptable. Machine tools are needed for the workshops, especially small lathes, drilling machines, planing machine, small tools and measuring appliances. For the Strength of Materials Laboratory the following are needed: Tension, torsion and compression testing machines, wire testing machine, extensometers, hardness testing appliances, impact testing machine and apparatus for microscopic study of metals. The Hydraulic Laboratory is not yet furnished with centrifugal pumps, Pelton wheel and turbines (up to 15 h.p. in each case), and also needs water meters and plunger pumps. Theodolites, levels, plane tables, &c., are required for the Surveying Department. For the Electrical Engineering Laboratories the authorities wish to obtain presents of the following equipment: Ammeters, voltmeters, wattmeters, testing sets, motors and generators (about 5 h.p.), two dynamos of 25 k.w direct-current 110 volts, switches and switch gear, transformers, rotary converter, motor generator (about 10 k.w.), rheostats, telegraph and telephone apparatus, wires, cables, and general fittings, and photometric appliances. Manufacturers in the United Kingdom who desire to present any of the above appliances to the University can obtain further information from the Secretary, British Engineers Association, Caxton House, Westminster, London, S.W. Apparatus will be carried freight free.

Fatal Steam Pipe Explosion.—On the 7th inst. a serious accident occurred on the steamship "Royal George," which is undergoing repairs in Messrs. Cammell, Laird's shipbuilding yard on the River Mersey. As a result of the bursting of a steam-pipe, three men were severely injured, and were removed to hospital. Two of the men have since died.

Fatal Crane Accident.—At the Westminster Coroner's Court, on the 6th inst., the inquest was concluded on a crane signalman who was killed while engaged on building works in High Holborn on April 24th. The deceased, owing to the chain of the crane breaking, fell a distance of 100ft. After the accident it was ascertained that there was a defective link in the chain. In the course of the enquiry Mr. F. J. Parkes, a factory inspector, said the quality of the workmanship of the links of the chain was very bad and the metal also was defective. He saw many signs that the links had been burned in the fire. The iron of which the chain was made appeared to him to be very rough, and he thought the nature had been taken out of it by the manner in which the welding was carried out. In his opinion the chain was quite unsuitable for the purpose for which it was used. The Coroner, in summing up, said the general question was a very grave one as to why such structures were allowed to be erected almost haphazard by builders in the streets of London. It was to him extraordinary that there was no supervision at all over such structures. From his enquiries, he had ascertained that no public authority had the power of inspection, and he thought it most regrettable that a Bill which had been introduced into Parliament to deal with the matter should have been read only the second time. In the interests of workmen and the general public, it was time that another Bill should be introduced by the Government giving the power of systematic inspection. The jury returned a verdict of "Accidental death," and added that inspectors should have the power of inspecting cranes.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Centrifugal pendulum governors. Kalb & Berner. 71.
Systems for starting engines. Kettering. 1424.
Centrifugal fans. Davidson. 1476.
Hole and pin gear wheels and pinions. Smith. 1660.
Smoke preventing apparatus for steam boilers. Porter. 3469.
Valve gears for engines. Bever. 6168.
Carburetters for internal combustion engines. Graham. 6622.
Internal-combustion engines. Noël 7194.
Valve mechanism for internal combustion engines with revolving cylinders. Lake. 9074.
Valve-gear systems for explosion motors. Tzaut. 9183.
Carburetters for internal-combustion engines. Wolseley Tool and Motor Car Company, and Lawrence. 9240.
Vice. Denz. 9305.
Apparatus for promoting circulation in steam generators. Hughes. 9344.
Means for preventing priming in steam generators. Hughes. 9345.
Boat propelling and steering gear. Bassford. 9389.
Carburetters for internal-combustion engines. Murchio. 9490.
Rolling metals. Wetcke. 9540.
Traction vehicles. Paine. 9621.
Superheaters for locomotives. Cusack & Morton. 9660.
Mechanical filters. Taylor & Chorlton. 9668.
Apparatus for operating railway and tramway points. Thomson. 9784.
Means for controlling flow and pressure in fluid-distributing systems. Mitchell. 9835.
Rotary engines. Cramp. 9915.
Gauging devices for railway tracks. Ivey & Hughes. 9945.
Starting devices for flying machines. Von Willisch. 10010.
Aerial machines. Balassanian. 10082.
Reduction or oxidation of metallic ore. Bourcoud. 10381.
Portable extensible conveyers. Fraser & Chalmers, Ltd., and Mitchell. 10626.
Devices for diminishing the rolling movement of ships. Stettiner Maschinenbau Akt. Ges. Vulcan. 11263.
Cranes. Weddell. 11269.
Means for keying devices to driving shafts. Jardine & Watchorn. 12287.
Metal tubes. Witzenmann. 12548.
Fire-bridges for furnaces. Marshall & Davies. 12803.
Protecting revolving or moving shafts and parts. Barlow and Whittle. 13307.
Pumping arrangements and water control in floating docks. Pritchard, and Swan, Hunter, & Wigham Richardson, Ltd. 13378.
Roller bearings. Hall. 14171.
Rivet and bolt making machines. Wallace. 14927.
Means for starting internal combustion engines. Johnson 15069.
Manufacture of composite metal tubes. Perrins. 15107.
Fluid-pressure engine. Kellington. 15176.
Internal combustion engines. Knight. 15445.
Liquid level-indicators. Bolton & Tyler. 15527.
Stuffing-boxes or packing devices for rotating shafts. Warwick Machinery Company (1908). 15588.
Carburetters for explosion engines. Alberti. 15652.
Valves for internal combustion engines. De Lissa & Motosacoche, Ltd. 15752.
Apparatus for the extraction of zinc. Jones. 15888.
Manufacture of cold pressed nut blanks. Lench 17366
Acetylene generators. Byrne, and Howes & Burley, Ltd. 17429.
Rotary engines, pumps, blowers, and exhausters. Gaydon and Gaydon. 19080.
Heating of regenerative chamber ovens Lengersdorff. 19812.
Steam pumps. Boult. 19933.
Valves for internal combustion engines. Frenzel 20092.
Railway block instruments McCloskey 20251
Liquid fuel pumps for internal combustion engines Lamplough, and D. Napier & Son, Ltd. 20954.
Flying machines. Clark. 21952.
Process for the treatment of refractory complex zinc lead ores. French. 22077.
Distributing device for automatic compressed air starting apparatus for internal combustion engines Gendron 23586
Manufacture of steel sheets for use in making tin plates Bevan 23679.
Driving and reversing and reducing gear. Savory 23934
Punches for sheet metal. Bruder Scherb. 23939.
Rotary engines, pumps, or meters. Kennedy Turbine Engines, Ltd 25035
Means for consuming smoke in boiler furnaces. Ogden 25639
Furnaces of boilers. Chadwick. 25657.
Motor vehicle. Torbensen. 26230.
Centrifugal pumps. Wilson & Craib. 27740
Treating feedwater for steam boilers. Hillman. 28166.
Furnaces. Weidemann. 28443
Float-cut files. Lockwood & Potts. 28541.
Rails for railways. Georgs Marien Bergwerkes und Hutton Verein Akt.-Ges. 28965.
Multi layer steel castings. Imray. 29720.
Railway-signalling apparatus. Tyer & Co., Firth, and Leake. 29890.

1913.

Steam superheaters. Hoffmann. 61.
Conveyer, specially adapted for use as a coal-face conveyer in collieries. Hirst. 1966.
Apparatus for forced lubrication. Turcat. 3647.
Rotary grate for gas producers. Rehman. 5108.
Centrifugal fans. Davidson. 5527 and 5528.
Expansion sockets for bolts. Gebhardt 5603.

ELECTRICAL, 1912.

Electric time switches. Reid. 1693.
System of electric generation and transmission for motor-driven vehicles, locomotives, or trains. Leitner. 9416.
Means for regulating the temperature of electrical heating and cooking apparatus. Kirkwood. 9513.
Electrical switches. Wynne. 13455.
Starting switches for electric motors. Fontecha. 13781.
Electrodes for arc lamps. Blondel. 14741.
Type-printing telegraphs and circuit-selecting apparatus. Jensen. 18985.
Electric fuses. Christians. 19533.
Supply of filtered air to dynamos. Mower & Hale. 19792.
Protective devices for electric circuits. British Thomson Houston Company. 20663.
Commutators for electric motors. Scott. 20828
Controlling apparatus for telephone systems using automatic selector switches. Molina. 21008.
Brush rocking apparatus for dynamos Pintschs Electric Manufacturing Company, and Vidal. 21433.
Ignition systems for motor vehicles. Riker. 22197.
Devices for automatically adjusting the time of ignition in internal combustion engines Robert Bosch. 24665.
Electric heating of houses. Lofquist. 25104.
Metal filaments for electric incandescent lamps. Westinghouse Metallfaden Gluhlampenfabrik Ges. 26289.
Joint boxes for electrical cables. W. T. Henley's Telegraph Works Company, and Nichols. 28094.
Electric arc lights. General Composing Company Ges. 28503.

1913.

Apparatus for producing perforated strip for telegraphically-transmitting signals. Siemens Bros. & Co. 942.
Means for the control of electric pressure and current regulators. Poole. 1765.

METAL QUOTATIONS.

TUESDAY, MAY 13TH.

Aluminium ingot	95/- per cwt.
,, wire, according to sizes, &c. ......from	112/- ,,
,, sheets ,, ,, ... ,,	126/- ,,
Antimony ......£32/-/- to	£33/-/- per ton.
Brass, rolled	$8\frac{3}{8}$d. per lb.
,, tubes (brazed)	$10\frac{1}{2}$d. ,,
,, ,, (solid drawn)	9d. ,,
,, ,, wire	$8\frac{7}{8}$d. ,,
Copper, Standard	£69/15/- per ton.
Iron, Cleveland	68/- ,,
,, Scotch	74/- ,,
Lead, English	£18/17/6 ,,
,, Foreign (soft)	£18/8/9 ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/10/- per bottle.
Silver	$27\frac{13}{16}$d. per oz.
Spelter	£25/5/- per ton.
Tin, block	£228/10/- ,,
Tin plates	14/3 ,,
Zinc sheets (Silesian)	£28/10/- ,,
,, (Stettin; Vieille Montagne)	£28/12/6 ,,

The Mechanical Engineer.

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Edited by
WILLIAM H. FOWLER
Wh. Sc., M.Inst.C.E.

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Explosions of Carbonaceous Dusts.

IT will be remembered that in November, 1911, two disastrous explosions occurred, attended with serious loss of life, one at a provender mill in Glasgow and the other at an oil cake factory in Liverpool. Expert evidence at the inquests clearly showed that the explosions were due to the ignition of carbonaceous dust, and indicated that though such disasters have not hitherto been of frequent occurrence, this is largely fortuitous, and that the conditions in many workshops where dusty matter is produced only require a combination of circumstances to become pregnant with danger. In view of this, the Home Office instructed Dr. Wheeler, the chemist attached to the Coal Mines Explosions Committee, to carry out a series of experiments with various kinds of carbonaceous dust at the Experimental Station at Eskmeals, and the result of these tests, extending over 12 months, are set forth in an interesting report by Dr. Wheeler issued by the Home Office. The investigation of the matter is the most exhaustive that has so far been made, and for this reason the report deserves the careful consideration of all occupiers of factories and workshops in which carbonaceous dust is generated. The 66 samples tested were not specially selected, but in all cases were collected by Factory Inspectors from beams, ledges, or other projections in the ordinary course of their visits.

Two methods of testing were employed, one to discriminate between harmless and dangerous dusts, and the other to ascertain the temperature at which inflammation of dangerous dusts takes place. As a result of these tests it was found possible to divide the samples of dust into three classes: (1) Those which ignite and propagate flame readily and require but a comparatively small source of heat for ignition, such as a lighted match; (2) those which readily ignite, but require a source of heat of large size and high temperature, such as an electric arc or the flame of a Bunsen burner; (3) those which do not appear capable of propagating flame under the conditions likely to obtain in a factory either

because (*a*) it is difficult to produce a cloud; or (*b*) because it is contaminated with large quantities of incombustible matter; or (*c*) because the material does not burn rapidly enough. The latter class comprised 30 samples of the 66 submitted, but some of these, though ranking as harmless, it is pointed out, might be capable of propagating flame if in a finer state of division or freer from incombustible matter, and only 20 of the samples submitted could be really so designated. Prominent in class 1, which includes the most dangerous dusts, are sugar, dextrine (calcined farina), starch, cocoa, rice meal, cork, wood flour, and oat husk. Flour, which has been responsible as we know for many sudden fires and explosions, is included in this class, but its inflammability is relatively inferior to the dust of maize, or even of tea.

For the purpose of determining the relative ignition temperature an ingenious apparatus was devised for producing a cloud of dust, which in each case was reduced to the same degree of fineness by passing through a 200 mesh sieve, and also for carefully recording the ignition temperature. The proportion of the sample which would pass through the sieve varied considerably, and hence the ignition temperature recorded cannot be regarded so much as that of the actual sample as of a possibility. The inflammability of combustible substances in general depends on the ease with which oxidation can be effected to produce flame and on the chemical affinity of the substance itself for oxygen. The smaller the state of sub-division, and the more rapidly, chemical affinity being equal, the combustion takes place. There are, however, other factors also to be considered in determining how far ignition temperature affords a measure of the inflammability of a dust. In the majority of those tested inflammable gases can be evolved from them by decomposition at quite low temperatures, and if any particular dust were allowed to remain in contact with a heated surface it might evolve gases in sufficient quantity to inflame with the surrounding air, and by this combustion cause inflammation of an adjoining layer of *dust and air*, and so cause propagation throughout the extent of the dust cloud. With dusts of widely different physical character it was difficult to secure uniformity of test conditions as regards density and velocity of dust cloud, but it is, nevertheless, interesting to note that the relative ignition temperature in no case exceeded 1,100° C., and in the case of sugar it was as low as 805° C.

Following these tests, others were made to determine the lowest temperature at which ignition could be effected. The ignitable mixture of gas and air (which originates the inflammation of the dust cloud), it has been pointed out, depends on the length of time the particles are heated, and given adequate time for destructive distillation, the temperature necessary for ignition is approximately that of the gases evolved which may be assumed to be mainly hydrocarbons, with carbon monoxide and hydrogen in varying proportions, and the ignition temperatures of which lie between about 550° C. and 750° C. With some dusts, of course, incombustible gases, such as nitrogen and carbon dioxide, may be evolved, and the effect of these is, of course, to raise the ignition temperature. Before making the final series of determinations with the different dusts, a series of experiments were made adopting various lengths of time for the passage of the dust cloud through the heating zone, and as was expected the longer the time of passage the better the chance for gaseous distillation, and the lower the temperature required for ignition. For comparative determination a constant velocity was adopted in each case, and in these, as in the previous tests, sugar and dextrine appear as the most readily inflammable of all dusts, the lowest temperature at which it was found possible to ignite them being 540° C., or well below a red heat. Most of the remaining dusts had practically the same minimum ignition temperature, ranging from 600° C. to 650° C. Dr. Wheeler's investigation shows that while it is impossible to draw any sweeping deduction respecting the inflammability of carbonaceous dust, owing to the many varying factors that enter into consideration, it is, nevertheless, desirable to exercise precautions in all factories where it is liable to be generated in quantity and liable to be deposited on beams or ledges, from which it may be projected in a cloud by some accidental circumstance, and brought in contact with some source of ignition, and, further, that dusts in many industries are more dangerous than has hitherto been supposed.

STANDARDISATION RULES FOR ELECTRICAL MACHINERY.

WE give below the Standardisation Rules which were provisionally adopted by the Council of the British Electrical and Allied Manufacturers' Association at their meeting on April 17th. They represent the work of the association upon the subjects of standard pressures and frequencies, high pressure and insulation tests, types of machines, rating, overloads and temperature rise. Other sections dealing with short-circuit tests, commutation, pressure regulation, parallel operation, efficiency and tolerances are at present under consideration.

SECTION I.—STANDARD PRESSURES AND FREQUENCIES.

(1) The standard frequencies for alternating-current work are 50 cycles per second and 25 cycles per second.

(2) The standard high-pressure systems for alternating-current work are 2,000, 3,000, 6,000, 10,000, and 20,000 volts.

(3) The standard generator pressures are: For direct-current generators 115, 230, 460, and 525 volts; for alternating-current generators 440, 550, 2,200, 3,300, 6,600, and 11,000 volts.

(4) The standard low pressures measured at consumers' terminals are: Direct current 110, 220, 440, and 500 volts; alternating current 100, 200, 400, and 500 volts: (Motors are to be capable of operating without injury at their rated outputs and overloads on any pressures not exceeding 5 per cent. above or below their standard voltages. See clause 6, sec. IV.)

5) *Transformers.*—The normal rated pressure of the low-tension side of a transformer is to be the same as that of the consumer's supply, according to clause 5. It is recommended that the standard transformer ratios should be such as to transform between the standard pressures above named.

SECTION II.—HIGH PRESSURE TESTS AND INSULATION RESISTANCE.

(*a*) *High-pressure Tests.*—(1) Commercial high-pressure tests are to be made on the completed apparatus while it is in good condition and before it is put into service. In the case of apparatus which has been in service reduced tests only are to be applied. Unless otherwise specified, the high-pressure tests are to be made at the makers' works. The test is to be made with a pressure of approximately sine wave form, preferably at the rated frequency of the apparatus, but in general any frequency between 25 and 100 is satisfactory. Prolonged tests at high pressure are undesirable, since they permanently weaken the insulation.

(2) The following tests are to be applied for one minute between the windings and the frame and core when the apparatus is at normal working temperature:—

Rated terminal pressure of circuit.	*Test Pressure.*
Not more than 333 volts.	1,000 volts.
Above 333, but not more than 1,500 volts.	Three times rated pressure with a minimum of 1,500 volts.
Above 1,500, but not more than 2,250 volts.	4,500 volts.
Above 2,250 volts.	Twice rated pressure.

Note.—In the case of machines driven by water-wheels and exposed to runaway conditions or otherwise exposed to possible excess pressure, it is recommended that pressure-limiting devices shall be provided, otherwise the test must be based on the highest pressure to which the windings may be subjected.

(3) High-pressure tests on field windings are to be based on the excitation pressure. Field windings of synchronous machines intended to be started from the alternating current side are to be tested at a pressure of 5,000 volts unless the field windings are provided with a "break-up" switch or will always be short-circuited at starting.

(4) Transformers are to have the same test between high-pressure winding and core as between high-pressure winding and low-pressure winding. In making such tests the low-pressure winding should be connected to the core.

(5) In general, constant-current apparatus, and apparatus used for series operation, is to have the test pressure rating corresponding to the maximum pressure which may be impressed upon the apparatus.

(*b*) *Insulation Resistance.*—(6) Very high insulation resistance (megohm test) should not be specified on electrical machinery, since in order to obtain it, long baking at high temperatures may be required, which may permanently damage the insulating material. Insulation resistance tests are of value in showing the condition of the insulation with special reference to moisture and dirt, and it is usually advisable to measure the insulation resistance before making high-pressure tests.

(7) In general an insulation resistance of 1 megohm for windings above 350 volts, or 0·25 megohm for low-pressure windings, is sufficient evidence that the windings are in condition to receive the high-pressure test.

Section III.—Types of Machines.

The following classification of rotating machines is recognised: (1) open, (2) protected, (3) enclosed-ventilated, (4) (*a*) pipe-ventilated, (*b*) pipe-ventilated with "forced draught," (5) drip-proof, (6) totally-enclosed, (7) flame-proof.

No. 1 requires no definition. No. 2. A "protected" machine is one in which the armature, field coils, and other live parts are protected mechanically from accidental or careless contact, while free ventilation is not materially obstructed. No. 3. An "enclosed-ventilated" machine is one in which the ventilating openings in the frame are covered with (*a*) expanded metal or wire gauze of not less than ¼in. mesh, so as not to obstruct free ventilation, (*b*) wire gauze, less than ¼in., but not less than $\frac{1}{32}$in. mesh, or with perforated metal having not less than $\frac{3}{16}$in. holes. (*c*) Machines having ventilating openings covered with screens having smaller openings than those specified in 3 (*b*) are to be treated as "totally-enclosed" machines as regards temperature rise and overloads. No. 4. A "pipe-ventilated" machine is one in which the frame is so arranged that the ventilating air may be conveyed to it through a pipe attached to the frame. If the heated air expelled from the machine is to be conveyed away through a second pipe attached to the machine, this should be so stated. It is understood that a pipe-ventilated machine propels its own ventilating air unless it is distinctly stated that the air supply is to be maintained by an independent fan external to the machine, in which case it becomes a "forced-draught" machine. No. 5. A "drip-proof" machine is one having a frame provided with ventilated openings, so protected as to exclude falling moisture or dirt. No. 6. A "totally-enclosed" machine is one in which the enclosing case does not allow a circulation of air between the inside and outside of the case, and is dust-proof, both as regards case and bearings. No. 7. A "flame-proof" machine is one in which the enclosing case can withstand, without injury, any explosion of gas that may occur within it, and will not transmit the explosion to any inflammable gas outside it. An induction motor in which the slip-rings and brushes alone are included within a flame-proof case should not be described as a "flame-proof" machine, but as a machine "with flame-proof slip-ring enclosure."

Section IV.—Rating.

(1) Two classes of rating are recognised—continuous rating and short-time rating (for intermittent working).

(2) The continuous rating is the output which a machine or a transformer will give for a period sufficiently long to attain practically constant temperature rise, and otherwise comply with these regulations. Unless otherwise specified, any machine rated to operate between two limits of pressure shall have its ampere rating determined upon the higher pressure.

(3) The short-time rating is the output which a machine or transformer will give for one hour, one half hour, or other specified period, and comply with these regulations. These ratings are called one-hour rating, one half hour rating, or other specified rating respectively.

(4) *Machines with Two or More Fixed Speeds* are to have a definite rating for each speed.

(5) *Variable Speed Machines.*—These are of two classes.

(*a*) Machines rated to give the same output throughout the entire range of operating speed. In such machines, the heating tests should be made at the lower limit of speed and commutation tests at the upper limit of speed.

(*b*) Machines which are not rated to give the same output at all speeds. These machines should have ratings specified for both minimum and maximum speeds.

(6) *Test Rating and Pressure Variation.*—Guarantees as to heating, efficiency and other characteristics are to be taken as applying to tests at the pressure marked on the nameplates, but motors must be capable of operating without injury at their rated outputs and overloads on any pressure not exceeding 5 per cent. above or below their standard pressures. It should be noted, however, that the "pull out" torque or maximum torque available will vary approximately as the square of the terminal pressure.

Section V.—Overloads.

(1) (*a*) Machines with continuous rating having limits of full load temperature rise in accordance with section VI. (*a*) are to be capable of withstanding 25 per cent. overload beyond the continuous rating for the following periods:—

100 kw. or h.p. and above	two hours.
Below 100 kw. or h.p., not below 25 kw. or h.p.	one hour.
Below 25 kw. or h.p., not below 2 kw. or h.p.	one half-hour.
Below 2 kw. or h.p.	five minutes.

(*b*) Machines with continuous rating having limits of full load temperature rise in accordance with section VI. (*b*) are to be capable of withstanding 15 per cent. overload beyond the continuous rating for the periods shown above.

(*c*) Machines with continuous rating, of the "totally-enclosed" class, having limits of full-load temperature rise in accordance with section VI. (*c*) have no overload ratings except the momentary overloads required in connection with commutation tests. The above overloads are to be measured in kilowatts, kilovolt-amperes, or horse-power according to the nameplate, except in the case of series or compound motors for which the overloads should be measured in amperes of input.

(2) With machines having two or more fixed speeds the above overload ratings are to apply at each speed. With variable-speed machines having ratings at minimum and maximum speeds, the above overload ratings are to apply at each speed. With machines having a speed range exceeding 2 to 1 and the same ratings at all speeds, the above overload ratings apply at any speed from the minimum to 75 per cent of the maximum speed.

(3) Motors with short-time rating are to be capable of carrying an overload of 100 per cent. torque for 30 seconds.

(4) Transformers are to be capable of withstanding overloads of 25 per cent. for two hours and 100 per cent for 30 seconds.

Section VI.—Heating.

(1) *Determination of Temperature Rise.*—The temperature rise of electrical machinery, both rotating and static, is to be taken as the difference between the cooling air temperature as defined in clause 6 and the temperature of the machines after giving their normal rated output for the following periods:—

(*a*) For machines with continuous rating: Until the temperature rise is practically constant; that is, until the rate of increase of temperature rise does not exceed 1° C. per hour. (This condition will usually be reached in less than six hours, except in the case of oil-immersed transformers.)

(*b*) For machines with short time rating: After working continuously for the period defined by the rating.

(2) *Permissible Temperature Rise.*—For machines with continuous or with short-time rating and designed to operate under ordinary conditions of cooling, *i.e.*, designed for an air

temperature of 25° C. (77° Fah.), the following temperature rises are the highest permissible at the normal full load:—

(*a*) Machines having Unobstructed Ventilation.

(*Section III., Classes* 1, 2, 3*a*, 4*a*, 4*b*.)

	Rise by thermometer.
All windings	40° C. (72° Fah.)
Cores in which windings are embedded	40° C. (72° Fah.)
Commutators and slip-rings	55° C. (99° Fah.)

In general the temperature rise by increase of resistance should not exceed 55° C. (99° Fah.) for alternator field coils, or 60° C. (108° Fah.) for shunt field coils of direct-current machines in this class.

(*b*) Machines having Partially Obstructed Ventilation.

(*Section III., Classes* 3*b*, 4*a*, *and* 5.)

	Rise by thermometer.
All windings	47° C. (85° Fah.)
Cores in which windings are embedded	47° C. (85° Fah.)
Commutators and slip-rings	55° C. (99° Fah.)

In general the temperature rise by increase of resistance should not exceed 65° C. (117° Fah.) for shunt field coils of direct-current machines in this class.

(*c*) Machines of the "Totally-enclosed" Class.

(*Section III., Classes* 3*c*, 6 *and* 7.)

	Rise by thermometer.
All windings	55° C. (99° Fah.)
Cores in which windings are embedded	55° C. (99° Fah.)
Commutators and slip-rings	55° C. (99° Fah.)

In general the temperature rise by increase of resistance should not exceed 70° C. (126° Fah.), for shunt field coils of direct-current machines in this class.

(3) *Transformers.*—The temperature rise of transformers is to be measured at their rated full load output, under the conditions specified in clause 1. It is permissible, however, to reduce the time of test by running for a time on an overload in current and pressure, then reducing the pressure to normal and maintaining at this until the required standard rate of temperature rise is attained. The limit of permissible temperature rise at the rated full load is as follows:—

Oil-cooled. By resistance or by thermometer in the oil 50° C.
Air-cooled. By resistance or by thermometer .... 50° C.

(4) *Machines for Tropical Conditions.*—For tropical conditions or other cases where the cooling air temperature is in excess of 35° C., the permissible temperature rises shown in the preceding clauses are to be reduced by 20 per cent. This does not apply to machines insulated with special heat-resisting materials in accordance with clause 5.

(5) *Special Heat-resisting Materials.*—The limits of temperature rise shown in clauses 2, 3, and 4 above apply to windings whose insulation consists wholly, or in important part, of cotton, paper, varnished cloth, or similar materials.

Higher temperature rises are permissible in the case of windings where asbestos, mica, or preparations of these materials are solely relied upon for insulation.

(6) *Measurement of Cooling Air Temperature.*—The air temperature is to be taken as the mean of the temperatures measured at regular intervals during the last quarter of the test period. When the machine under test is provided with pipe ventilation or forced draught, the air temperature is to be measured by a thermometer placed in the current of incoming air.

In the case of machines other than those referred to in the preceding paragraph, the air temperature is to be taken as the mean of the readings of two or more thermometers placed not more than 6ft. from the machine and on a level with its centre on opposite sides. So far as possible, these thermometers should be placed so as to measure the current of air flowing towards the machine, but they must not be exposed to radiation or stray draughts.

(7) *Correction for Altitude.*—When a machine is intended for service at high altitude, the permissible temperature rise, if tested near sea-level, is to be reduced 2½ per cent. for each 1,000ft.

Tests of Locomotive Springs.—In some recent tests of locomotive spring steel made of oil-tempered chrome-vanadium steel an elastc limit of 256,000lbs. was reached. In the tests oil-tempered carbon steel springs developed an elastic limit of 101,000lbs., and chrome-nickel springs one of 134,500lbs.

COCHRANE'S REVOLVING CYLINDER INTERNAL-COMBUSTION ENGINE.

In engines of the revolving-cylinder type, lubricating oil is apt to collect on and around the under-side of the pistons under the action of centrifugal force, and the accumulation is sometimes sufficient to act as a coating which is a non-conductor of heat, thus causing overheating of the pistons and consequent binding thereof in the cylinders. To avoid this difficulty, the inlet valves have been fitted in the pistons so that the carburetted air, passing therethrough from the crank case, sweeps off the oil and carries it into the cylinder. Such arrangements, however, do not permit of adequate control of the petrol and air supply, and also there is always the dangerous liability of the valve failing to operate properly and a consequent accumulation of petrol in the crank chamber, which may be the cause of an explosion therein.

To overcome these disadvantages the engine illustrated herewith has been designed and patented by Mr. W. Cochrane, 26D, Clarges Street, London, W. Fig. 1 is a sectional elevation of the engine. Figs. 2 and 3 are cross-sections of the rotary valve and its casing, the sections being taken at 4—4 and 5—5 of Fig. 1. Fig. 4 is a cross-section through the carburetter, and Fig. 5 is a diagram illustrating one mode of driving the rotary valves. Each cylinder A is provided with a series of air ports B, in a position where they will be uncovered by the piston C when it reaches the end of its suction or explosion stroke. The piston C is provided with ports D to coincide with those in the cylinder. The ports are in the form of circular holes, and those in the piston are flush or approximately flush with the under face E of the piston C, upon which the oil is apt to accumulate. In this way, as the air rushes in through the ports B and D it sweeps over the under face E of the piston and carries off any oil which may be on it. The air which is drawn into the crank case J by the cylinder or cylinders which happen to be under suction is passed through a perforated hollow crank shaft K, and thence, by ducts L, to the various inlet valve boxes.

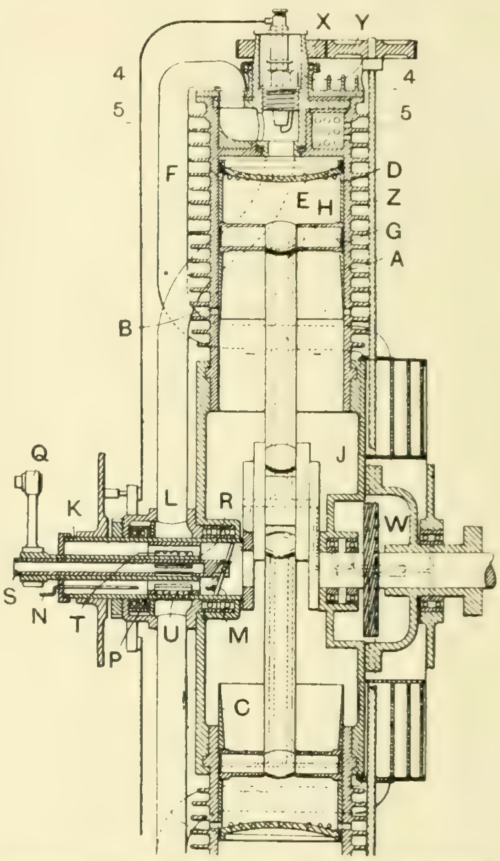


Fig. 1.—Cochrane's Revolving Cylinder Internal-combustion Engine.

In order to permit of control of the air supply, the inner end of the crank shaft is fitted with a throttle valve M. When this valve is in one position no air can pass, but when it is moved, for instance, by a rod N, air can pass and mix

with petrol fed in from a float feed device, and the carburetted air can then pass to the cylinders. A second valve is provided to regulate the passage of the explosive mixture through the perforations in the shaft. This regulating valve P is of cylindrical form and revolves or oscillates inside the perforated portion of the shaft K, being operated from outside the casing by a lever Q. The valve P is so arranged that it also controls the petrol supply. It is connected to a perforated central sleeve or valve R, which rotates or oscillates on the petrol supply pipe S. The valve P has slots T, adapted to be brought opposite to the perforations U in the shaft K,

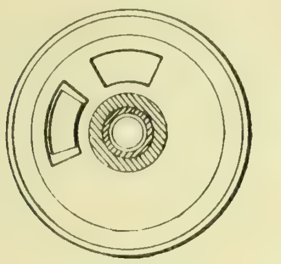


Fig. 2.

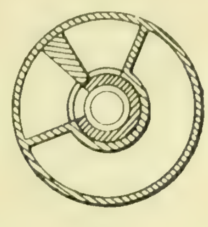


Fig. 3.

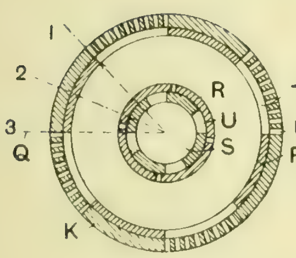


Fig. 4.

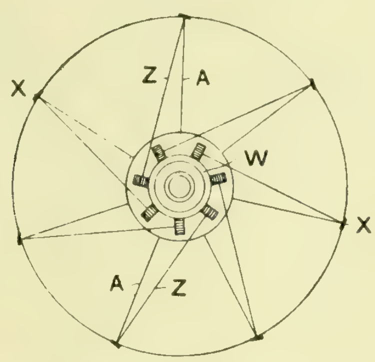


Fig. 5.

Cochrane's Revolving Cylinder Internal-combustion Engine.

while the valve R has perforations adapted to be brought over slots U in the petrol pipe S. By moving the lever Q into position 1 (Fig. 4) the valves are so set that only air is admitted. On further movement of the lever into position 2 the air supply is diminished, while a maximum supply of petrol is secured. When the lever Q is moved into position 3, both the air and petrol supplies are cut off. The valves are rotated by gearing X, Y driven by shafts Z, in turn driven off a helically cut gear wheel W on the engine shaft, the shafts Z having pinions meshing with wheel W, which drive the shafts Z in the required ratio.

STANDARD SPECIFICATION FOR COPPER TUBES AND THREADS.

The Engineering Standards Committee have just issued their Standard Specification (No. 61) for Copper Tubes and their Screw Threads (primarily for domestic and similar work). The standardisation of copper tubes was first considered in connection with a report made by the late Mr. Henry Lea to the Sectional Committee on Screw Threads and Limit Gauges in October, 1911. The consideration of this subject, together with the question of standardising union joints and other tube connections, resulted in the appointment of the Sub-Committee on Metal Tubes and Connections, which appointment was confirmed by the Main Committee on July 18th, 1912. The Sub-Committee have adopted British standard pipe threads for the heavier gauge tubes, and the recommendations of the Sectional Committee on Screw Threads and Limit Gauges as to the gauging of pipe threads have been largely followed in this report. In drawing up their recommendations, the Sub-Committee availed themselves of the information previously obtained by the Joint Committee on Screwed Copper Pipe Standards appointed by the Institution of Heating and Ventilating Engineers and the National Association of Master Heating and Domestic Engineers, and record their appreciation of the information placed at their disposal by the Joint Committee and of the pioneer work undertaken by them.

ROLLING-MILL PRACTICE IN THE UNITED STATES.*

BY J. PUPPE, D.ING.

(Continued from page 550.)

Wire Rod Mills (Table III.).

The wire industry belongs to the more recently established branches of the steel industry of the United States, the production of wire rods and wire nails having been developed in the 'eighties. The great importance of the wire rod and wire manufacturing industry in America is apparent from the statistics of the iron and steel trade in 1909; for instance, the production of rails was 3,111,583 tons, of structural steel 2,275,562 tons, and of wire rod 2,335,685 tons. This enormous output of wire rod, which exceeded that of structural steel, and was only about 20 per cent. less than that of rails, is explained by the fact that not only the home requirements are supplied, but that a large export trade in wire and wire nails has been built up. From 1894 to 1908 the export of wire rose from 20,329 tons to 174,690 tons, and that of wire nails from 10,394 tons in 1898 to 43,559 tons in 1908. The practice of wire rod rolling differs from the German and British practice in that practically the only size rolled is No. 5—5·4 mm. diam., or about $\frac{7}{32}$in. No. 6, which is the usual size in Europe, is hardly ever manufactured. But the American wire rod differs not only in diameter, but also as regards the quality of the finished product. The rods vary considerably from a true circular section, so much so that in many cases they can hardly be called round iron at all, whereas in German practice a good circular section is the rule. One disadvantage of making rods of irregular section is that very heavy wear and tear of the draw-plates results in drawing the wire, and it is now almost the universal practice to use chilled metal for the draw-plates, as steel plates will not stand. It is considered, however, that it is a more profitable thing to aim at a large production than to bestow care upon these technical details, attention to which is less necessary on account of the fact that most of the important wire rolling-mills have wire-drawing works attached to them, which have no option but to take the material supplied by the mill in connection with which they work.

It is undoubtedly possible to obtain a larger production by rolling a thicker size of wire rod, but calculation would probably show that any advantage so gained is completely neutralised by the increased number of rejections, a greater expenditure on draw-plates, and a larger number of drawing operations. In fact, the cost of working up wire rods of special quality, of No. 5 hardness or upwards, such as are used for wire ropes and other special purposes, would be prohibitive if they were not accurately round, a fact which no doubt accounts for the importation of wire rods of high quality when required for special purposes.

With regard to the arrangement of wire mills, the older type, known as the Belgian, also the German or Garrett type, are still in use as well as the continuous mill, which has been brought to a high degree of perfection by the Morgan Construction Company. It is scarcely necessary to do more than to refer to the existing literature where these mills are fully described, although a few characteristic details may be mentioned. In the first place, the continuous wire mill has been more and more widely adopted, which is no doubt due to the fact that the continuous type, while giving nearly as large an output as the Garrett mill, is more economical on account of the very small amount of labour required to serve it. The quality of the finished product of a continuous mill is, however, much inferior to that of a Garrett mill, which, in the author's opinion, is due not only to the practice of rolling several wires alongside of one another, which is also a feature of the Garrett mill, but principally to the fact that the rod is liable to be stretched between the several stands, and the effect of this straining is at once noticeable in the finished rod. The stretching is primarily due to variations in the structure and dimensions of the billet as well as to the uneven heating of the billet and blowholes in the material, and it is quite impossible to control or entirely to remove these defects. In rolling flats, tube strip, or hoop iron in continuous mills, the difficulty is met by means of special guides, it being absolutely necessary to guard against a reduction of

* Paper presented at the annual meeting of the Iron and Steel Institute, May, 1913.

section due to stretching in the case of such material, as the pieces would be useless if they were of uneven thickness. But, in the case of wire rod, the main object, as before stated, is to get a large output rather than a high quality of rod, the home consumers being dependent on the manufacturers on account of the high protective duty.

In the five wire rolling-mills which were inspected, five entirely continuous mills were noted, and only one Garrett mill. The continuous mills are always arranged in two sections, six stands generally forming a roughing train in which the bar is first rolled down and afterwards finished in the subsequent continuous stands. The number of stands depends upon the initial section, but there are generally 16 stands, the initial section of the billet being $1\frac{3}{4}$in. by $1\frac{3}{4}$in. The continuous wire-rod mills of the American Steel and Wire Company, on the other hand, use 4in. billets in the older Garrett mills, and have retained this size in the newer continuous mills, for the reason that their cogging and billet mills produce such billets very economically. The two continuous mills (Nos. 2 and 5) consequently consist of 21 and 20 stands respectively. In No. 2 mill the two groups of stands are arranged at right angles to one another, and the rod, after roughing down, is turned round through an angle of 90°. Between the turning table and first finishing stand a reheating furnace is interposed. The five roughing stands might be regarded as a billet mill, especially as the 16 finishing stands are further sub-divided into two sets, between which a shears is interposed. One of the largest wire-rod mills is that of the American Steel and Wire Company at Waukegan (No. 5), in which one continuous roughing train of eight stands supplies an entirely continuous mill and two mixed mills with material. The bar, about $1\frac{7}{8}$in. square, coming from the continuous roughing rolls, is led to the three trains, in which it is immediately finished in several loops. The performance of the roughing mill is quite remarkable, and shows how well the continuous mill is suited to the conditions of a large output. The eight stands deal with the whole production, averaging about 800 tons per 24 hours, the maximum achievement being 957 tons. As this is on a scale with the performance of a continuous billet mill, this roughing train may also be characterised as a billet mill rather than as a rod mill.

According to the foregoing, the economy and capabilities of the continuous mills may be summed up under two heads, namely, output and quality of product. The output, as has been noted, is exceedingly high, but, on the other hand, the product is not of high quality. The special applicability of continuous mills would therefore be to the production of semi-products, such as billets, flats, or wire rod. As roughing trains for merchant mills or mills for hoops and small sections they are not to be recommended from the point of view of output, especially where several merchant mills require to be served. Another drawback is that the stretch of the rod between two stands, with the resulting variation in section, cannot be guarded against, and this, under European conditions, would inevitably lead to the rejection of the material. The only simple Garrett mill observed was that of the American Steel and Wire Company (No. 3), which consists of two cogging stands and three roughing and finishing sets. The 4in. billet is rolled down in 18 to 22 passes, according to the required thickness of the wire rod. In comparing the advantages and disadvantages of the two types of wire rolling mills, the fact has to be taken into consideration that with the latest type of Garrett mill the number of hands required to serve the mill has been reduced by the introduction of "repeater" guides, and these mills now require no more labour than the continuous mills. The roll diameter of the wire mills is stated to be 10in., though it may be assumed in the case of the non-continuous mills that the diameter of the last stand of rolls is somewhat larger, in order to prevent the loops becoming too great.

The great outputs of the wire rolling-mills are obtained by a comparatively heavy pressure on the rolls such as soft material can readily stand, but, above all, by employing, in the continuous mills, a very high rate of speed on leaving the rolls. In non-continuous mills the speed is limited to about 22ft. to 25ft. per second, as this is the maximum speed at which it is possible for a man to catch the end of the rod. This would be about the speed in the wire rolling-mills in Germany. In the American continuous mills, on the other hand, the speed of the wire on leaving the rolls, as shown in Table III., is 3,350ft. per minute, or 56ft. per second, whereas in the only German continuous wire rolling-mill at Esch the speed with which the wire leaves the roll is not more than 48ft. per second.

TABLE III.—*Wire Rod Mills.*

No.	Name of Company and Place.	Type.	No. of Stands.	Particulars of Drive. Type.	Dimensions.	Revolutions	Capacity (H.P.).	Roll Diam.	Initial Section.	No. of Passes	Speed of Leaving Rolls.	Output.
1	Jones & Laughlin Steel Co. (Aliquippa)	Continuous	16	Flywheel compound	865/1620 × 1370	100	2080 I.H.P.	6 stands 12in. 10 stands 10in.	$1\frac{3}{4} \times 1\frac{3}{4}$in.	16	3350ft. per minute	194 tons in 12 hours
2	American Steel and Wire Co. (American Works)	Continuous Continuous	5 16	Flywheel compound	—	—	1400	10in.	4 × 4in.	21	3350ft. per minute	1 bundle finished in 40 seconds
3	American Steel and Wire Co. (American Works)	Garrett	2 roughing	Flywheel compound	—	—	1000	—	4 × 4in.	18–22	—	200 tons in 12 hours
			3 ; 1 loop 4 ; 2 loops 4 ; 3 loops	Flywheel compound	—	—	3300	10in.	—	—	—	—
4	Youngstown Sheet and Tube Co. (Struthers)	Continuous	16	Horizontal-vertical compound engine	860/1625 × 1220	—	–	—	$1\frac{3}{4} \times 1\frac{3}{4}$in.	16	—	—
5	American Steel and Wire Co. (Waukegan)	Continuous	8	1 flywheel engine (bevel wheels)	—	—	2500	15in.	4 × 4in.	8	—	—
		Half-continuous: Continuous	12	1 flywheel engine (bevel wheels)	—	—	2000	10in.	$\frac{7}{8}$ diameter	12	—	—
		Half-continuous: 3 loops	11	2 flywheel engine (belt)	—	—	1200 each	10in.	$\frac{7}{8}$ diameter	11	—	—
		Half-continuous: Continuous 1 loop	4 2	1 flywheel engine (belt)	—	—	1200	10in.	$\frac{7}{8}$ diameter	10		
		Half-continuous: 1 loop	4	1 flywheel engine (belt)	—	—	1200	10in.	$\frac{7}{8}$ diameter	10		—

SLABBING AND UNIVERSAL MILLS (TABLE IV.).

The slabbing mill with vertical rolls is a type of mill which is not familiar in European practice. In discussing cogging mills in Part I. of the paper, it was mentioned that the latter are not available for rolling billets in different sections, and particularly slabs, as they are kept fully occupied in

supplying material to the mills forming an integral part of the installation. A kind of modification of a cogging mill has been developed which serves both for cogging in the ordinary way and for rolling slabs and flat blooms. The American slabbing mill is a universal mill with two reversible horizontal rolls and two or three vertical rolls running in housings of special construction. Such mills are used for rolling out blooms and universal plates, also for heavy square billets. Or the vertical rolls can be removed from their bearings and the mill used for rolling thick plates. With the vertical rolls it can also work as an ordinary cogging mill, and, by using grooved rolls, I-girders can be roughed down on it, as at the Lackawanna Steel Company's works. Thus, in the case of this mill, it is to be noted that the manufacture of various intermediate products is concentrated in one

Within the author's knowledge an attempt has been made in Germany to adopt the latter form of construction in a universal mill for slabs of 44in. maximum width down to strip under 8in. width. The lack of success was due not to any defect of design, but simply to economical causes, as it did not pay to roll narrow strips in a heavy universal mill requiring motive power sufficient for driving the mill when working on material of the maximum size. In other respects, too, these slabbing mills are of very massive construction, being designed to take ingots and slabs averaging 6 to 7 tons and sometimes 10 tons in weight. The following weight figures give some idea of the size of the Lackawanna slabbing mill: Bed-plates, 161 tons; bed-plate girders, 69·7 tons; housings for horizontal rolls, 115 tons; housings for vertical rolls, 81·5 tons; pinion housings, 63 tons.

TABLE IV.—*Slabbing and Universal Mills.*

No.	Name of company and place.	Type.	Particulars of drive. Horizontal rolls. Type and dimensions.	Revolutions.	Gear ratio.	Vertical rolls. Type and dimensions.	Gear ratio.	Rolls. Horizontal. No.	Dimensions. (mm.).	Vertical. No.	Dimensions (mm.).	Class of material rolled.	Output
1	Lackawanna Steel Co.	Slabbing Duo	Twin reversing engine 1,168 1,524	-	2·25 : 1	Reversing engine, 914 1,219	1·5 : 1	2	813 dia. · 1829	3	559 dia.	Slabs up to 1,372 762 mm. Universal plates, blooms, billets, rough-shaped for I-beams over 9-in. depth.	—
2	Lackawanna Steel Co.	Universal No. 5 Duo	Reversing engine 8,000 h.p.	-	-	2 reversing engines. 1,397 1,524	Direct coupled	2	762 dia.	4	445 dia.	Universal plates up to 1,219 mm. wide. Blooms up to 1,825 mm. wide.	150,000 tons yearly
3	Carnegie Steel Co. (Homestead).	Slabbing Duo	Twin reversing engine, 1,168 1,524 3,200 h.p.	-	19 : 37	Reversing engine, 711 1,220	22 : 32	2	815 dia.	2 (In special housings)	508	Slabs and blooms.	—
4	Carnegie Steel Co. (Homestead).	Universal Duo	Twin reversing engine, 1,067 1,524, 3,200 h.p.	84	25 : 29	Same engine.	—	2 (Reinforced by 2 rolls of greater dia.)	660 dia.	4	410	Universal plates or armour up to 1,000 mm. wide.	1,500 tons daily
5	Carnegie Steel Co. (Homestead).	Universal Duo	Twin reversing engine, 1,270 1,524 5,900 h.p.	75	Direct coupled	Same engine	-	2	915 dia.	4	445	Plates up to 1,220 mm. wide.	585 tons daily, 10,300 tons monthly.
6	National Tube Co.	Slabbing Duo	Twin reversing engine, 1,165 1,524	—	5 : 7	Twin reversing engine, 915 1,220		2	815 dia. 1650	2	890 dia.	Plates from 356 1,030 mm. wide Slabs for universal mill.	220,000 tons in 1910.
7	National Tube Co.	Universal Trio (Lauth)	Tandem compound, 4,000 h.p.	80 135	-	Same engine.		3	-	2	635 dia. 1450	Plates from 230 1,080 mm. wide very thin.	
8	Indiana Steel Co. (Gary).	Universal Trio	A.C. induction motor, 6,600 volts, 25 cycles, 4,500 6,000 h.p.	40 80	4 : 3	Same motor	-	3	900 dia. × 2,150	4	510 880	Plates 350 1,525 mm. wide 7-50 mm. thick. Maximum length 43 m. Blooms up to 1,825 mm. wide.	Plates 36 m. 1 423 9·5 mm. are rolled in 19 passes from a slab 1,423 1,524 254 mm Time, 82 secs.; reduction, 16 per cent.
9	Illinois Steel Co.	Universal Duo	Flywheel induction D.C. generator, Ilgner-Leonard control; starting dynamo, 3,000 kilowatts, 600 volts; A.C. induction motor, 1,300 h.p. two motors at 2,000 h.p., 575 volts.	Synchr. 375 300	Direct coupled	Same motor	-	2	610 dia. 1,700 (Journal 457 dia.)	4	356 dia. 330 (Journal 203 dia.)	Plates 165 750 mm. wide, 12·7 50·8 mm. thick; maximum length, 24 m.	75,000 tons yearly.
10	Youngstown Sheet and Tube Co.	Universal Duo	Twin reversing engine, 1,120 1,524			Same engine.		2				Plates up to 1,040 mm. wide. Blooms up to 1,680 mm. wide.	

unit, in contrast to the prevailing practice of specialisation, by running a whole plant on one class of product only.

The arrangement of three vertical rolls (Fig 2), of which one is driven by the friction of the bloom (No. 1, Lackawanna Steel Company), is such as to permit the rolling of slabs and blooms to as great a width as possible, without unduly weakening the mill, and also to give a better grip of the piece. The same object is attained in the slabbing mill of the National Tube Company by mounting the vertical bevel gear wheels on two special shafts, which permit the horizontal bevel wheels to clear one another when the rolls are brought close together. In order to cause them to bite better, the vertical rolls are roughened. In the Lackawanna mill it is possible to roll slabs of a minimum width of 18½in., and in the National Tube Company's mill, of 14in. At the same time there is sufficient room for bevel gear wheels of an exceptionally heavy design, the pitch circles of the wheels in the present cases being 57in. and 52in. respectively.

The total weight of this rolling mill, including roll beds and engines, is 1,900 tons. The comparatively small roll diameter of 32½in. in all the slabbing mills inspected is due to the very compact construction and short length of roll body, but it permits of reducing the cross-section in large percentages at a time with a low power consumption. In the presence of the author a plate, 66¼in. wide by ⅜in. thick, was rolled down from a slab measuring 37in. by 4½in. by 6ft. 2in. long, in 15 passes, the time being 74 secs., corresponding to an average reduction of section of 12 per cent. per pass, which is a very high rate.

In all the universal mills inspected except one the arrangement differs from the usual German arrangement in having a pair of vertical rolls on both sides of the stand. This has the advantage that both in the trio and reversing duo the piece is worked in each direction under equal conditions. That the practical importance of such an arrangement is not of much value is shown by the fact that this form of construc-

tion has been abandoned in newer mills, or, at all events, is now very seldom adopted. Constructional considerations are also opposed to it, as a second pair of vertical rolls only adds to the chances of a breakdown.

There was also noted at the works of the National Tube Company a 3-high Lauth mill, which rolls plates of great length, ranging from 9in. to 42in., and of extreme thinness. The mill is very compactly built in order to ensure even thickness in the plates. It is driven by a 4,000 h.p. engine, the revolutions of which can be varied from 80 to 135 per minute, so that the roll speed may be increased as the plate cools during rolling. Plates measuring 120ft. long, 23½in. wide, and ⅛in. thick were rolled and finished in 75 secs.

A 3-high mill with the rolls all of equal diameter was seen at the works of the Indiana Steel Company. The method of driving this mill, which may be regarded as standard for trios, will be discussed further on. The universal rolling mill

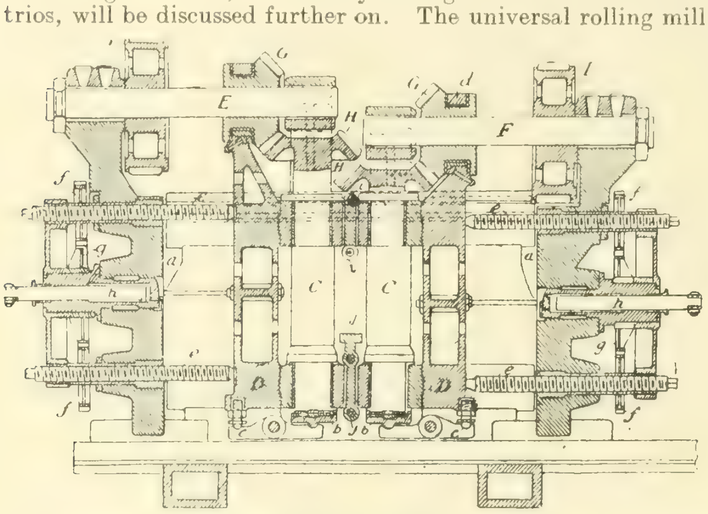


FIG. 2.—DRIVING ARRANGEMENT OF VERTICAL ROLLS IN SLABBING MILL OF THE NATIONAL TUBE COMPANY.

of the Carnegie Steel Company at Homestead shows a peculiar arrangement. It has a reversing 2-high mill with a pair of vertical rolls on either side of the stand; the horizontal rolls are stiffened by idle rolls of nickel steel, larger in diameter than the driven rolls, and placed one above and one below these. Hard armour plates of considerable width are rolled, and the high production of 1,500 tons in 24 hours is only rendered possible by this construction, especially as the diameter of the horizontal rolls is somewhat small for the conditions. The American universal mills are mostly arranged so that the vertical rolls can be removed for rolling sheets, which is a particularly useful feature, as they can then work on sheets for stock when not full up with orders for universal plates. The mills are made to take plates as wide as possible; for instance, at Gary plates from 14in. to 60in. in width are rolled, whereas in Germany 43in. is seldom exceeded.

(To be continued.)

The Junior Institution of Engineers.—On the 29th anniversary of the foundation of the Junior Institution of Engineers, Monday, June 30th, 1913, at the Institution of Electrical Engineers, Victoria Embankment, the second Gustave Canet lecture will be delivered by Dr. Dugald Clerk, F.R.S., who has chosen as his subject "The Working Fluid of Internal-combustion Engines." The late M. Gustave Canet (Past President of the Institution of Civil Engineers of France) was President of the Junior Institution of Engineers in 1907-8, his death occurring at the close of his term of office. In accordance with a wish he had expressed, Madame Canet, MM. Paul and Albert Canet, and their families, presented a sum of money to the Institution to form a gold medal, in commemoration of his presidency. This gold medal is awarded quadrennially to an officer or member of the Institution invited by the Council to deliver a lecture on a subject of importance to the engineering and scientific world. The first award was made in 1909, the lecture on "The Engineering of Ordnance" being delivered by Lieut. (now Sir) A. Trevor Dawson, R.N., M.Inst.C.E., M.I.Mech.E. (President of the Institution 1912-13), who will preside on the occasion of Dr. Dugald Clerk's lecture.

PRACTICAL OPERATION OF GAS ENGINES USING BLASTFURNACE GAS AS FUEL.*

BY CHARLES C. SAMPSON.

THE question of the operation of gas engines using blast-furnace gas as fuel includes several important factors outside the actual operation of the engines themselves. The usual blast-furnace gas has the following composition: Carbon monoxide 23 per cent., carbon dioxide 12 per cent., hydrogen 2 per cent., methane 2 per cent., vapour of water 3 per cent., nitrogen 58 per cent., and a calorific or heating value of about 900 cal. per cubic metre, and gives a consumption of 3 cub. m. per indicated horse-power in the engine.

Cleaning of the Gas.—One of the most important of these factors and one which held back the general use of these engines many years is the cleaning of the gas. As delivered by the furnaces to the down-comer the gas contains normally from 3 to 10 grains of dust per cubic foot of dry gas, but at times of slips or other sudden changes in the furnace, it carries much more. For use in engines the gas must be cleaned at most to 0·02 grains of dust to satisfy the requirements of the engine builders, but even this figure is too high to satisfy the operating engineer, since it is possible to clean

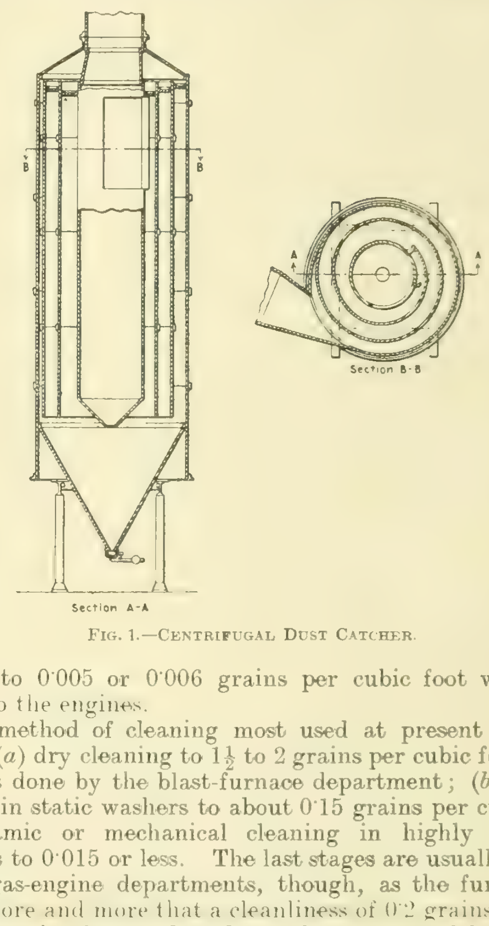


FIG. 1.—CENTRIFUGAL DUST CATCHER.

the gas to 0·005 or 0·006 grains per cubic foot with great benefit to the engines.

The method of cleaning most used at present has three stages: (*a*) dry cleaning to 1½ to 2 grains per cubic foot, which is always done by the blast-furnace department; (*b*) primary washing in static washers to about 0·15 grains per cubic foot; (*c*) dynamic or mechanical cleaning in highly developed machines to 0·015 or less. The last stages are usually handled by the gas-engine departments, though, as the furnace men realise more and more that a cleanliness of 0·2 grains per cubic foot or less is of great benefit to the stoves and boilers they will take over the second stage, leaving only the final cleaning for the gas-engine department.

The dry cleaning is done in dry dust catchers, the standard design being a large diameter, vertical, cylindrical shell into which the gas enters tangentially near the top and leaves through a vertical outlet pipe which extends about two-thirds down from the top. These dust catchers remove the heavier particles of dust, but their efficiency is only about 80 per cent. as they pick up, or perhaps do not drop, the finer dust which is carried on by the upward current of gas to the outlet.

The refinement of design in dry cleaners has advanced materially in the past three or four years, as shown in the modern apparatus resulting from the careful study of the problem. One of the latest of these is the centrifugal dust catcher shown in Fig. 1. This device makes use of the centrifugal separation of dust from the gas as it passes inward through a cylindrical spiral opening into a dust basin at the

* Paper presented before the American Society of Mechanical Engineers.

bottom. The gas enters at the top of the outside, leaves at the top of the inner end of the spiral and passes upward through an extension of the pipe around which it is wrapped. The gas passes free of all obstructions at the upper end of the spiral while the dust separated drops to the bottom through the open end. There is no tendency for the gas to pick up the separated dust and carry it out as is the case in the older types of dry cleaners.

It is frequently found that sudden changes in the direction of flow of the gas, as at water seals or other necessary bends in the pipe, are quite efficient in the removal of the dust. In one case gas carrying about 5 grains per cubic foot passed through four sharp bends and gave all dust but about 2 grains per cubic foot. For this reason every part of the dry gas main where such bends are necessary can be made to assist materially in the cleaning of the gas, if pockets are added equipped with valves so that the dust can be conveniently removed.

Where long gas mains are necessary they can be made to add to the cleaning of the gas by building them in successive lengths with sufficient rise and fall to allow the dust to settle in pockets at the bottom angles for cleaning. If the gas for any reason moves slowly in a long main the loss of heat through the pipe will probably reduce the temperature below the dew point and thus condense some of the moisture carried with the gas from the furnace and cause the deposit of wet dust which adds greatly to the cleaning plant labour. This is specially apt to occur where two or more groups of furnaces supply one washing plant; the gas from the one with the lower top pressure will move slowly or even reverse its direction of flow at times, allowing excessive cooling and the resulting condensation. This condensation will begin when the temperature is reduced to 115° to 120° Fah. and will of course give more trouble in winter when the condensed moisture will freeze in the dust valves and drips and require continual thawing to allow its removal.

It is possible to keep the gas mains clean without taking them out of service if they are equipped with sufficient openings to allow every part of the pipe to be reached with a stream from a high-pressure water system, and with valves or doors at all low points for the removal of the mud washed down. The mains near the furnace of course do not need this equipment as they can easily be designed to make them entirely self-cleaning, while it is quite necessary that long mains where condensation may occur be so equipped.

The present primary washers (the first stage of wet cleaning) are of the static scrubber type and include all those in which the gas passes through a stationary shell without moving parts, the water for washing being supplied either in spray or sheets. The spray and hurdle, Mullen, baffle, and rain type scrubbers come under this classification. The spray and hurdle system is preferred on account of its better distribution of water, and since it is self-cleaning it needs inspection only after long periods of operation. Several of these scrubbers have been opened after from one to three years' service and in every case have been found perfectly clean and required no repairs whatever before being returned to service. The wood was in good condition, as it is continually wet and oxygen does not have access to it to start decay. In the rain or baffle types the gas is more apt to channel and travel up one side of the scrubber and the water down the other.

It is important to secure uniform distribution of the gas as well as of the water in any scrubber. For the inlet a cone about two-thirds the diameter of the shell with a cone-shaped ring below it open in the centre about one-half the diameter of the shell will give good distribution. These should both slope about 45° to keep the mud from remaining on them. Two outlets at opposite sides of the top are better than one on account of the deflection of the water by the gas currents if only one is used. This is particularly true if the water is sprayed by falling on spray plates as the gas current may then be strong enough to blow the water clear of the plate and thus entirely lose its effect. Spray nozzles are not subject to this fault but are not able to handle water that has much dirt in it without a great amount of attention.

In designing the scrubber bottom, its foundation and the basin and overflow for the outlet water, it must be remembered that while the usual working pressure will be from 6in. to 18in. of water, a slip will give pressures of from 40in. to 50in. for a short time. A normal head of water of 36in. from the bottom of the scrubber to the water overflow level with the basin walls 24in. above this and an emergency overflow 4in. below the top of the basin walls will care for slip pressure without blowing out any gas or overflowing the basin into the yard. The bottom of the basin wall will be self-cleaning if it has a steep slope and the outlet pipe is from the centre of the bottom. The whole design of scrubber and basin must be examined to eliminate all places where mud can remain long enough to cake. Fig. 2 shows this arrangement of scrubber bottom.

Should the water overflow pipe be stopped even for a short time the heavy mud will settle to the bottom of the basin and when the overflow pipe is cleaned there will be such a quantity that even the extra head of water to the emergency overflow will not force it out. For this reason the forming of heavy chunks must be prevented as much as possible and provision must be made for stirring the basin water both with hoes or rakes and with a stream of water from the end of a pipe which can be thrust into all parts of it. It will be found convenient also to have the pipe bent at the end so that the stream can be directed up the overflow pipe to furnish additional head for starting the flow when necessary, or a special pipe with return bend and short nipple to thrust down the overflow pipe itself will surely be able to start the flow.

The final stage in cleaning is done with mechanical scrubbers or washers. These are highly developed, and the

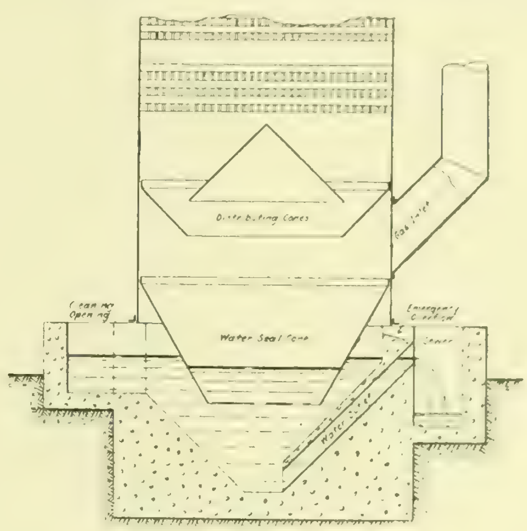


FIG. 2.—SCRUBBER BOTTOM.

Theisen patented gas washer has been in the lead for several years, though other types are now being worked out, their builders claiming better results with less water and power consumption than the Theisen. The Theisen washers require about 3 per cent. of the power plant output for their operation and from 16 galls. to 18 galls. of water per 1,000 cub. ft. of gas cleaned, which, added to the 75 galls. to 80 galls. required in the scrubbers, makes the total from 90 galls. to 100 galls. for the whole cleaning process. The newer apparatus, which are along the lines of the mechanical disintegrator, claim to use about 20 galls. of water per 1,000 cub. ft. of gas for the whole cleaning process and to operate on less power than the Theisen washers.

Holders. — In blast-furnace gas engine plants the engines are entirely dependent upon the continuous supply of gas from the furnaces; a 100,000 cub. ft. capacity holder can only be considered a pressure regulator with capacity for enough gas to allow retiring in good order when the gas supply is cut off for any reason. Thus in a 1,000 kw. plant with such a holder the gas on hand would operate the plant only for about 25 to 30 minutes and should not be counted on for more than 15 to 20 minutes. This in an emergency would give time to notify the various departments using power and allow them time to prepare for a shutdown.

The quantity of gas consumed by the engines is regulated by the governor to suit the power output, but since they must be supplied with gas at uniform pressure for satisfactory operation, it is necessary to regulate the gas supplied by some type of gasometer. This is best done by a gasometer of a capacity such that the pressure fluctuations are not noticeable

at the engines, and since it is well to have an emergency quantity of gas the gas holder itself will meet both demands at once if supplied with an efficient regulation valve. The holder will regulate the pressure perfectly between the maximum limit of the total quantity of gas that can be forced through the mains with the furnace pressure available assisted by the gas washers and the minimum limit of the leakage at the regulating valve.

There should also be the possibility of regulating the gas quantity at the secondary washers, since at times of very light loads the gas pressure between the holder and washer may blow out drip seals or cause dangerous gas leaks. This can be cared for by the installation of butterfly valves with quadrants either before or after the mechanical washers. The latter is to be preferred for then the gas remains longer in the washers and receives additional cleaning. A good regulating valve at the holder is a butterfly valve attached by means of levers and cables to the holder bell so that it will remain wide open until the bell rises within a few feet of its upper position, and close gradually till at the highest position it is completely closed. The arrangement shown in Fig. 3 works satisfactorily. The weight A must be heavy enough to close the valve and the weight B must be heavy enough to open the valve and also lift the weight A.

All exposed water lines must be protected from freezing. This is especially true of the supply to seals, drips from the gas main, and any line that does not have a continuous flow. With good water separators after the secondary cleaning apparatus, freezing weather or even 8° or 10° Fah. below zero will not cause trouble in the gas mains themselves, though any

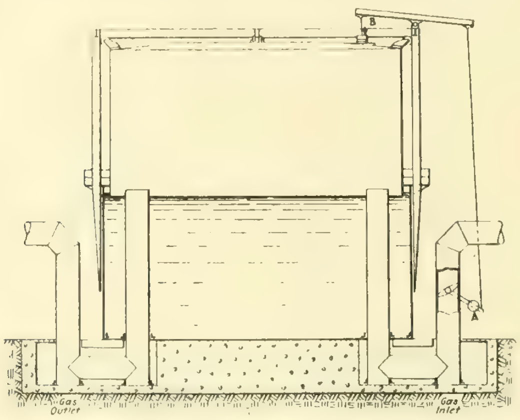


FIG. 3. -ARRANGEMENT OF REGULATING VALVE FOR GAS HOLDER.

valves which may be nearly closed or which are closed part of the time must be carefully protected. The butterfly valve for regulating the gas should be enclosed in a tight box with steam coils to keep it in working order. This also is true of the valves at the gas-washing plant unless it is possible to install them within a heated building.

The water in the gas holder must also be warmed. The exhaust from the regulating valve coil will easily keep the holder water warm enough to prevent freezing, except in the coldest weather (under 0° Fah.), when it is usually necessary to supply additional steam through several nozzles arranged to set up a circulation of the water around the tank. These should be well down in the water or ice will form on the lower part of the shell and build in toward the centre and prevent the lowering of the bell. During the time the holder water is warmed it is important frequently to observe its temperature; if too hot it will charge the gas with water so that condensation and freezing will take place in the gas engine supply pipes. When the water circulates properly in the holder it is not necessary to have it any warmer than 38° or 40° Fah., while a rise to 65° or 70° will give trouble.

If the gas holder is not visible from the gas-washing plant the operator needs a visible signal to give him its position, also an audible signal to inform him if it should lower beyond safe working position, the amount of the drop allowable before the audible signal operates being determined by the position of the regulating valve at the holder. The drop should be less than an amount to give a complete opening of the valve. The gas-washer operator should have telephone connections with the engine-room, besides the usual whistle or bell signals which are used to notify him of the starting or stopping of engines. He should also be in close touch with the blast-furnace department in order that any change in the gas supply can be known in advance.

Relief Doors.—In all gas-pipe lines so-called explosion doors are installed. These are as a rule useful only for access to the main for cleaning, usually being made of cast iron and hinged; on account of their weight and method of attachment the moment of inertia is so great that they will not open quickly enough to prevent the destruction of the main in which they are installed. Any gas main that will support itself over the span usually employed will easily stand any pressure that can be produced in the cleaning plant, and the use of these valves or other relief valves is not necessary. The inconvenience of escaping gas makes it advisable to design them as cleaning doors only, and to arrange them with a clamp fastening to avoid this inconvenience. If it is thought necessary to install explosion doors or valves I would suggest the use of sheets of light material arranged in frames so that they will be blown out should an explosion occur in the main. The best protection from explosions is careful operation, especially to guard against a reduction of pressure of gas at the furnace side of the cleaning plant due to no air being drawn into the main at the stoves, and to see that no piece of apparatus is put in service with air trapped so it can be mixed with the gas and sent along to the engines.

Recording Instruments. — Thermometers and pressure gauges for indicating the temperature and pressure of the gas: entering the cleaning plant, between the primary and secondary washers leaving the latter, and before and after the gas holder, form important parts of the gas-cleaning system. The ordinary gas works thermometer with a stem reaching about 8in. to 10in. into the gas mains are to be located at each of the above points, while pressure gauges of the U-tube type with inches of water as a measure of the pressure can be located in the gas-washer building and connected to these points by ⅜in. or ½in. gas pipe. Recording gauges should be used in connection with the indicating water column for the gas pressure at the entrance to the cleaning plant and in the gas main leading to the gas holder.

Log Records.—The successful operation of the gas-washing plant is very much advanced by the proper understanding of the meaning of the variation shown by these thermometers and gauges. For this reason it is important to keep a record of these variations on carefully designed daily log sheets with at least eight daily notations. The gas-washer operator soon learns to interpret the gauge and thermometer changes and will often foretell serious trouble by such understanding. For instance, the partial filling of a water seal is indicated some time before it will cause trouble by the swinging of the water in the U-tube, this movement being so markedly different from any other that he knows at once the trouble and from the location of the gauge can easily tell which seal is filling. The daily log sheets should have space reserved for the operator to note any unusual occurrence and the work done to keep the plant in condition. It should be in fact a complete report of each day's work to the engineer in charge, keeping him in close touch with the changing conditions in the gas-cleaning system.

Engine Starting.—A second most important factor in successful gas-engine operation is good engine operators, and the same characteristics which are valuable in steam-engine operators are valuable in the gas-engine engineer. The operation of the engines themselves is exactly similar as far as the running gear is concerned, and it is only the fact that the gas engineer is fireman as well as engineer that makes it necessary that he be more alert and watchful. Economical operation of gas engines on the same account requires that the engine operator must have his sense of "the feel of the machine" well developed.

Compressed air at from 150lbs. to 200lbs. per square inch pressure has proved satisfactory for starting gas engines and is especially desirable on account of the ease with which a suitable quantity can be stored under pressure ready for use at any time. In a starting system of 2,000 cub. ft. capacity the air pressure is lowered about 20lbs. in starting one 3,000 kw. twin-tandem unit, and since 150lbs. pressure is sufficient for a start there is a possibility of at least three starts from 200lbs. initial pressure, which is certainly sufficient to get under way even during the excitement of an emergency shutdown. Record was kept of the pressure drop in starting an 1,800 h.p. twin-tandem Allis-Chalmers engine from an air system having

two tanks of 1,100 cub. ft. capacity each. This record included 19 starts, 16 using the full capacity of the system and three with one tank out of service. This record is plotted in Fig. 4, the pressure in the system being shown as ordinates and the pressure drop as abscissæ; the 16 starts with complete air system in use are indicated by circles and the three that were made with one of the air tanks shut off by crosses. It may be noted that the quantity of air required to start the engine was about the same, regardless of the pressure in the air tanks.

The necessary capacity of air tanks and air compressors for a given plant depends upon the number and size of engine units, and the frequency with which they may need to be started. After the engine operator becomes familiar with the operating peculiarities of the engines he should be able to start them at intervals of from 4 to 8 minutes and not lower the

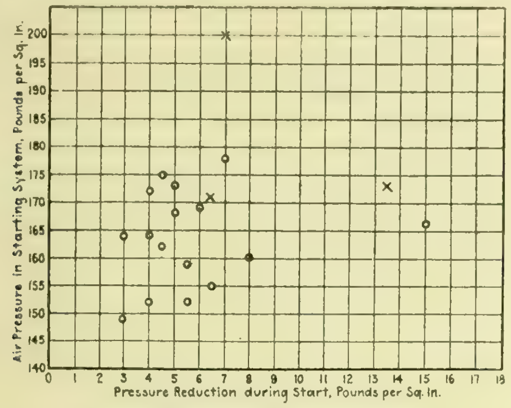


FIG. 4.—RECORD OF PRESSURE DROP.

air pressure more than the compressor can make up in that time; if an engine lowers the pressure 8lbs. per square inch in a 2,000 cub. ft. capacity system, the compressors should compress 8/15 of 2,000 = 1,060 cub. ft. free air in the maximum time allowable between starts or, say, 10 minutes. This would require two 106 cub. ft. compressors. For the ordinary blast-furnace gas-engine plant of from three to six engines two air compressors of 100 cub. ft. capacity and air tank capacity of 2,000 cub. ft. are quite sufficient, while for more than six engines the compressor capacity should be increased rather than the tank volume. At least one of the compressors must derive its power from some source outside of the gas engine in order to be able to start the plant if all units should be down.

It is important to keep the water jackets thoroughly clean and the item of jacket cleaning should appear regularly in the engine operation schedule. This cleaning requires careful attention since, with the class of labour usually put on this work, it will be slighted in the places where the most care is needed.

Lubrication, Cleaning Oil.—The question of lubrication is one of so many variations I can only say that for general lubrication of such as main bearings, crosshead and crank pins and crosshead slides where the rubbing surfaces are at room temperature, an oil of the following physical characteristics has given excellent service: Specific gravity 888, viscosity (Tagliabue) 210 at 70° Fah., cold test 35° Fah., flash temperature 435.

This service also includes satisfactory separation of water and dirt by settling and filtration. On account of the almost certain mixing of water from the cooling system with the system oil, it is necessary to provide means of separating the water and oil in the filtration process and it can be done thoroughly only by heating the oil to about 160° or 190° Fah. and giving it time in a quiet condition to allow the separation. A large part of the dirt will settle in the water. Such that does not must be removed by filtration through fine cloth either of organic fibre or of fine wire. The latter is more to be desired because of the ease with which it can be cleaned.

A good oil-cleaning system giving excellent satisfaction consists of one 1,500 galls. water-separating tank, shown in Fig. 5, with a heating coil over which the oil flows as it enters on returning from the engines, and an adjustable automatic water overflow to discharge the separated water, two settling tanks of the same size through which the oil passes in tandem to allow time for quiet settling of dirt particles, and a filter unit with 20 filter bags, 10 each in two filter tanks.

An extra tank is used when either of the other three is out of service for cleaning. An auxiliary tank of about 200 galls. capacity is used for "boiling up" the sludge taken from either of the large tanks or the filters at time of cleaning as well as such dirty oil as can be drawn off daily from the bottom of the overhead oil tank. This system is shown in Fig. 6. The oil from the engine drips enters tank A over the steam coil, flows down through the inner cone then up and out the overflow to C and D, thence to the filters F and G through E, which is also a water separator. The clean oil is pumped from the filters by one of the pumps at K, which are in duplicate, to the overhead engine supply tank in which the quantity of oil on hand is shown by an index on a large gauge visible from the engine-room floor. Gauge glasses on each tank show the level of the line between the oil and water, both as an operating convenience and as a means of checking the quantity of oil used during the month. The separated water flows down the inside of the cone in A to the bottom of the tank from which it flows through the automatic overflow H. The nipple in the tee at H is adjustable, so that the water in A can be held at the level found best in operation.

A part of the dirt is oil coated, so that it floats between the water and the oil and will accumulate until its removal is necessary. The oil from the engines is then turned into tank B, the supply to C and D being kept up by stopping the water overflow and filling A with water as long as good oil flows out. The water is then drawn off to the sewer and the sludge pumped into the boiling tank J where as much oil is reclaimed as possible. The other tanks are cleaned in the same way. There are pipe connections from the bottom of all tanks to one of the pumps, also from the discharge of this pump to the tank J. Such an oil system will keep the oil clean for a plant circulating 500 galls. to 600 galls. per hour. Of course some oil is lost through leakage at the engines, and some is wiped up in keeping the engines clean, but the addition of new oil need not amount to more than 100 galls. per month. In blowing-engine plants where the engine oil is drawn into the blowing cylinders from mechanically operated valves the oil consumption will not be so low unless good oil separators are installed in the cold blast mains arranged to discharge this oil back into the oil system.

The cylinder oil question is also one of many opinions. The varying cleanliness of the gas, hardness of cylinder walls and

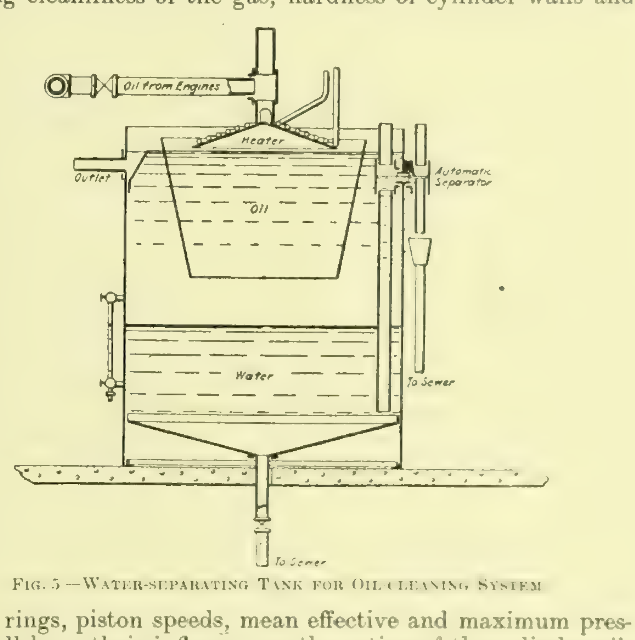


FIG. 5.—WATER-SEPARATING TANK FOR OIL-CLEANING SYSTEM

piston rings, piston speeds, mean effective and maximum pressures all have their influence on the action of the cylinder oil. An oil showing a specific gravity of 0·902; viscosity (Tagliabue) of 78 at 212° Fah., and a flash temperature of 380, gave excellent results in a gas blowing-engine plant where the dust was low (0·01 or less) and piston speeds less than 600ft. per minute, and was not satisfactory in another, with 0·012 dust and piston speeds of 850ft. per minute. In the latter case the oil was replaced by one of specific gravity, 0·920; viscosity, 203 at 212° Fah.; and flash temperature, 502, and immediate improvement was shown. With the lighter oil the cylinders were not dry in any part, though they did show more wear than was expected for the time in service, the machining marks in the bore being almost invisible after three months' operation.

The cylinder oil can be put in a tank in the basement and piped to all cylinder oil pumps by using compressed air at 15lbs. per square inch. This provides opportunity for the installation of oil meters to keep accurate account of the oil used on each engine, or the supply tank may be equipped with graduated gauge glass and record kept of the supply to the whole plant.

Ignition. — The mechanically-operated igniter is much to be preferred over the magnetic type. The current supply should be from a source not liable to fluctuation, such as that from a motor generator set that supplies current to the ignition system alone and arranged in connection with a storage battery so that should anything happen to the motor generators the battery would take up the load, automatically signalling the operator. The location of the ignition plugs is important, since an explosion on one side only of the piston will force it to the other side and cause it to strike the cylinder wall. This is easily apparent in cylinders having the combustion chamber at the side and the effect of one-sided explosions can be seen when one of three equally spaced igniters is not working.

Premature ignition is usually caused by excess hydrogen in the gas, and will occur when the quantity of hydrogen reaches 4·6 per cent., depending also upon the cleanliness of the cylinders. This prematuring is one of the first indications of leaking cooling plates in the furnace, and the gas-engine operator will often be able to inform the furnaces of this condition before they learn of it themselves. When a furnace has the wind off for casting, the water pressure in the cooling plates is greater than the furnace pressure and the water enters the furnace and is immediately dissociated, the oxygen being consumed by the coke leaves the excess hydrogen in the gas. When the wind is put on again this gas, rich in hydrogen, is sent along to the engine, causing prematuring.

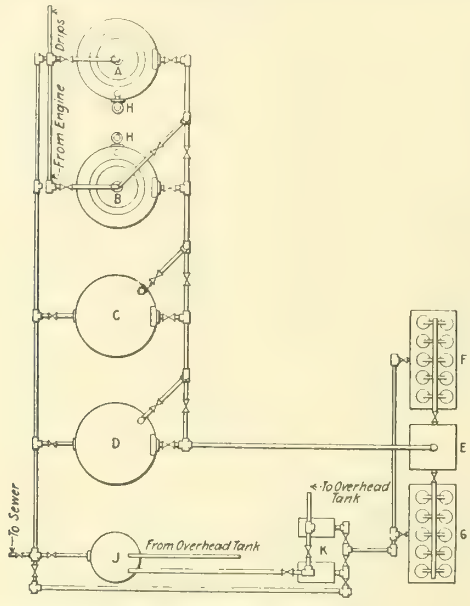


FIG. 6.—OIL-CLEANING SYSTEM.
A and B, water separating tanks; F and G, filters; J, boiling tank.

Miscellaneous Information. —The pistons of the early large gas engines were of cast iron, but these gave considerable trouble by cracking because they were not properly ribbed. Several builders changed to cast steel, but found they gave trouble either by cutting the cylinder walls or by beading over and binding the rings. Cast iron was again resorted to with an improved design. In the cast-steel pistons also the movement of the rings widens the grooves, so that in a short time there is too much clearance, which necessitates turning the grooves and making new rings.

Cast-iron snap rings of uniform cross-section give better service than any other type. This has been learned after many attempts to design a complicated ring, the designer believing a ring to hold gas-engine pressure would be more difficult to make than one for steam-engine pressure.

Piston-rod packing furnishes one of the difficult problems for the designer and also for the engine operator. A good packing must be simple in design and, as in the case with the piston rings, the forms with the fewest parts seem to give the best service. Both cast iron and babbitt have given good results. The success or failure of this part of the engine depends largely upon its cleanliness and too much care cannot be used in assembling it to ensure its proper application.

The engine room basement has not received the attention it deserves. Two items the designer of any power plant will do well to consider are: make the engine-room floor high enough over the basement floor to allow 6ft. clear under all suspended pipes, and have the basement floor slope enough for rapid drainage (at least 12in. for 100ft.). A dry basement with plenty of head room is easily kept clean and a clean basement is a great help in keeping the whole room in good condition. Ventilation and lighting are also more easily accomplished in a high basement.

The question of safety of the employé in all occupations is at present a live one and is to be considered in the engine-room as well as in the rolling mill. Safety demands the elimination of all dangerous conditions by covering gears, guarding flywheels, generators and crossheads, enclosing electrical apparatus, and keeping all gas pipes tight and free from leaks. The men must be trained to watch out for their own and their fellow-workmen's safety. It is just as important that the lives and limbs of the engine crew be protected as it is that the cost of electricity should be low.

Complete records of operation are invaluable, as it is only by the study of accurate record of the actual happenings that we can hope to improve. It is not possible to trust to memory for a comparison of the results of different types or arrangements of apparatus.

A daily log of the various pressures and temperatures must be kept to learn whether the plant conditions are changing and to know the cause of these changes. Any unusual occurrence or the regular recurrence of repairs noted on the log sheets puts the information regarding the plant where it can be used in predicting and preparing for the future. Not only should this information be kept daily but it should be collected and averaged monthly and yearly for the comparison of month with month and year with year. Much of the engineering information is best shown graphically, for a sheet full of figures does not give a true conception of the actual conditions.

The original information is necessarily furnished on the daily log sheets written by the shift engineer and he should be supplied with a copy of the resulting data sheets. He is just as much interested in the power plant as is the chief engineer, and this information cannot be placed anywhere to do more good than with the engine operators. The rate of progress in the gas-engine field depends entirely upon the rapidity with which engineers are able to gain understanding of this machinery, and the collecting and compiling of these records is of the greatest service for this purpose.

FORMATION OF DEPOSITS IN OIL-COOLED TRANSFORMERS.

IN a paper on this subject by Mr. A. C. Michie recently read before the Newcastle local section of the Institution of Electrical Engineers, the author dealt with some of the chemical changes which occurred in transformer oils during use, and more particularly with the formation of the solid matter which deposited on the windings and other parts of transformers. These deposits varied in appearance from pale yellow soft sludges to dark brown or black hard masses, and their presence materially affected the circulation of the oil and led to overheating of the windings. Various theories had been offered to explain the formation of these deposits. They had been supposed to be due to the deposition of solid paraffins from the oil, to the separation of suspended solid particles under the influence of electrical stresses, to the disintegrating action of the oil on the varnishes and other materials used on the windings, and to the polymerisation of the oil under the action of heat.

It was, he observed, well known that electrical stresses might cause a separation from oils having solid matters in suspension, and it was true that most mineral oils carried a minute quantity of solid matter in colloidal solution, but it was rather difficult to imagine how the electrical stresses could affect a transformation of the liquid oil into the solid sludge. Pairs of sheet-metal electrodes 4in. by 1½in. were set a distance of 2½in. apart and placed in a series of glass tanks containing different qualities of transformer oils. A pressure of 20,000 volts was maintained between each pair of electrodes for three weeks, but not a trace of deposit separated out from any of the oils tested. The author showed later that electrical

discharges might have an influence on the formation of these deposits through the generation of ozone. Some of the first samples of sludge examined gave, when ignited, an ash containing appreciable quantities of lead. The presence of this metal seemed to confirm the view that the deposits were derived from the varnish of the windings, lead oxide being largely used as a drier in the preparation of boiled linseed oil. In some other samples, where no lead was found, traces of manganese were detected. Manganese oxalate was also used as a drier. The evidence of the lead was rather weakened some time later when some large masses of a transformer deposit of a specially refractory nature were examined. The material was unusually hard and dense, and on closer inspection proved to be the compound of red lead and glycerol largely used for cementing joints. Lead alloys were also used in lining some transformers, and mineral oils under certain conditions were capable of attacking and forming solid compounds with lead. In only one instance had a deposit been obtained in which it could be definitely ascertained that it was entirely derived from the windings. In this case the freshly varnished windings had been immersed in the oil before proper drying and hardening had set in. The deposit in this case was quite different from what was usually obtained, and there was no difficulty in detecting the linseed oil used in the preparation of the varnish. Not only was it impossible to detect any quantity of varnish or other insulating compounds in the majority of deposits, but the quantity of deposit was frequently far too great to be accounted for in this way, and deposits also occurred in transformers in which the use of varnish was avoided. In most cases the deposits must be mainly derived from the transformer oil itself.

It had, the author remarked, been suggested that these deposits were produced by the influence of the heat of the transformer, but this was not confirmed experimentally. Analyses of transformer deposits showed that these contained a considerable proportion of oxygen, and as the original oils were free from oxygen the only conclusion that could be drawn was that the formation of these deposits was brought about by the oxidising influence of the air on the transformer oils. In all likelihood there was a simultaneous polymerisation of the oxidised molecules. A sample of the sludge taken from a transformer gave the following analysis: Carbon 76·0, hydrogen 7·1, oxygen 16·9 per cent. In order to confirm the oxidation theory various samples of transformer oils were subjected to the action of a current of air at a temperature of 150° C. Different transformer oils when tested in this way by bubbling air through them gave strikingly different results. Generally the oils darkened in colour and increased in acidity, but whereas in some cases the oils remained clear and bright, in the majority of cases they became turbid from the formation of solid matter. In order to determine the amount of solid matter which separated out, the oils were diluted with petroleum spirit and filtered. The solid residue after freeing from oil by washing with petroleum spirit was then weighed. In some cases no deposit was obtained, while in others it weighed as much as 2·5 per cent. of the weight of oil taken. These differences in the behaviour of different samples were not surprising in view of the different chemical characters of the oils, the method of distillation, and the degree of refinement. Deposits obtained by treating mineral oils with air closely resembled what was obtained in transformers. A deposit obtained in this way gave the following figures on analysis: Carbon 74·27, hydrogen 6·62, oxygen 19·11 per cent. In both cases the deposits were almost insoluble in petroleum spirit, but readily soluble in benzol. The melting or softening point varied from about 70° C. to about 220° C. for different deposits.

It might be objected that the test conditions were not comparable with those in the actual transformers, in particular that a temperature of 150° C. was too high, and that the maximum temperature obtained by the oil in transformers seldom exceeded 100° C. There was, however, evidence that, although the mean temperature of the oil might not rise above 100° C., local overheating of the windings sometimes occurred, and certainly judging from the boiled-up and carbonised appearance of certain deposits taken from windings, a temperature very considerably over 100° C. must have been attained. Although a temperature of 150° C. had been chosen for these tests, on account of the greater rapidity of the oxidising action, the formation of sludge no doubt took place at comparatively low temperatures if the period of exposure was prolonged, and there were still other conditions in a transformer which accelerated the formation of sludge.

The presence of ozone in the air of the transformer greatly increased the rate of sludge formation, and by using ozonised air a heavy deposit was obtained from an oil in a comparatively short time at 90° C. The rate of sludge formation was accelerated by the presence of certain metals, notably copper. In every instance examined copper was found to have a very pronounced influence in increasing the quantity of sludge which separated out in a given time. The greater the surface of metal exposed to the oil the greater was the influence on the rate of oxidation. Thus an oil which when treated with air in the absence of metals gave no sludge after 45 hours, gave 0·5 per cent. of sludge when the test was repeated on another portion of the same oil containing copper foil of 15 sq. in. surface, and 1·8 per cent. of sludge when 25 sq. in. of copper was used. The copper, which as a rule was only very slightly attacked, did not enter into the composition of the deposits, and here, as in many other oxidation processes, played the part of a catalytic agent. In the case of lead, the metal generally showed signs of corrosion, and entered into the composition of the deposits, which were of a characteristic pale-yellow colour. In one deposit 36 per cent. of lead was found.

The quantity of sludge which separated out in the oxidation process was, he said, largely dependent on the degree of refinement of the oil. As a general rule the more an oil was refined the more stable it became towards oxidising agents. In the usual processes of refining mineral oils, these were either treated successively with concentrated sulphuric acid and caustic soda or they were made to pass through filters containing fuller's earth or similar material, or a combination of both methods might be employed. In both processes the unsaturated and more readily oxidisable portions of the oil became removed. Samples of oil were treated by both these processes and were found to give, under the air oxidation test, a very much smaller quantity of sludge than before refinement. Thus an oil originally giving 1 per cent. of deposit was found to give after treatment only 0·1 per cent. of deposit.

Although several transformer oils were on the market, which when subjected to the oxidation test gave no deposit after 45 hours, no oil had been met with which did not give rise to deposit after prolonged treatment. In one instance an oil withstood the test for 150 hours without a deposit appearing. All oils oxidised in time, but it was only reasonable to expect that those which came out well on the oxidation test would also behave well in the transformer. Apart from the question of the quality of the oil, the design of the transformer had to be considered, and in this connection, if the formation of deposits was to be avoided or minimised, the following conditions should be avoided: (1) Over-heating, (2) undue access of air to the oil, (3) conditions likely to give rise to the formation of ozone, (4) contact of the oil with clean surfaces of copper, iron, and lead.

Locomotive Workshops for Victoria.—The Victoria Railway Commissioners have decided to build locomotive workshops at Bendigo and Ballarat. The preparation of the plans is being expedited and tenders will shortly be called for the work. The approximate cost of the equipment at each workshop will be about £28,000. It is believed that the work will be rapidly pushed to completion.

Report on the Cadeby Mine Disaster.—The Home Office has just issued as a Parliamentary paper the report of H.M. Chief Inspector of Mines on the causes of, and circumstances attending, the explosions which occurred at Cadeby Main Colliery, near Doncaster, on July 9th last year, and which resulted in the loss of 88 lives, including a rescue party and three Government inspectors. The report considers the explosion was due to the fact that a fire, originating years ago, was never completely eradicated. Instructions for the purpose were well conceived, but the inspector does not believe they were completely carried out. He refrains from attaching blame to anyone in particular. He also considers that, whilst there was provided at the colliery as fine a body of trained men as one could wish for, the organisation at the mine on the occasion of these explosions was most defective. All unauthorised persons should have been prevented from entering the mine to attempt the rescue, and there should have been no immediate attempt to recover the bodies after the first explosion. The loss of life in the second explosion would then have been considerably less.

ALL GEAR DRIVE FOR BORING AND FACING MACHINES.

We illustrate herewith a design of boring and facing machine fitted with an all-gear drive, the invention of Mr. W. A. Pearn, Birchfields Road, Rusholme, Manchester. The machine is provided with the usual tool-holder A carried by the boring or facing head B and traversed by the bevel gears C and screw and nut D shown. The mandrel E upon which the face plate or boring and facing head B is mounted is rotated from the pulley F (see Fig. 2) in the base of the machine by the following means. A sleeve G rotating loosely upon the mandrel E has mounted thereon the pulley H and the pinions Z, J, the pulley H being rotated from the pulley F by the belt or chain K which passes round the pulleys F, H and the tensioning pulleys M, N, whereby the tension of the belt or chain is maintained constant notwithstanding variations in the vertical height of the mandrel E. A further pinion O is keyed upon the mandrel E, and a spur wheel P is secured to the face plate or mandrel end as shown. A second shaft or spindle Q is provided upon the machine, having mounted thereon spur wheels R, S, T, and the pinion U. The spindle Q can be moved longitudinally by the hand wheel V. Such movements result in putting the pinion U out of or into engagement with the spur wheel P and the spur wheel T into or out of engagement with the spur wheel O upon the mandrel. The spur wheels R and S which are feather-keyed upon the spindle Q are moved into or out of engagement with their respective pinions J and Z by means of the rack W and pinion shown.

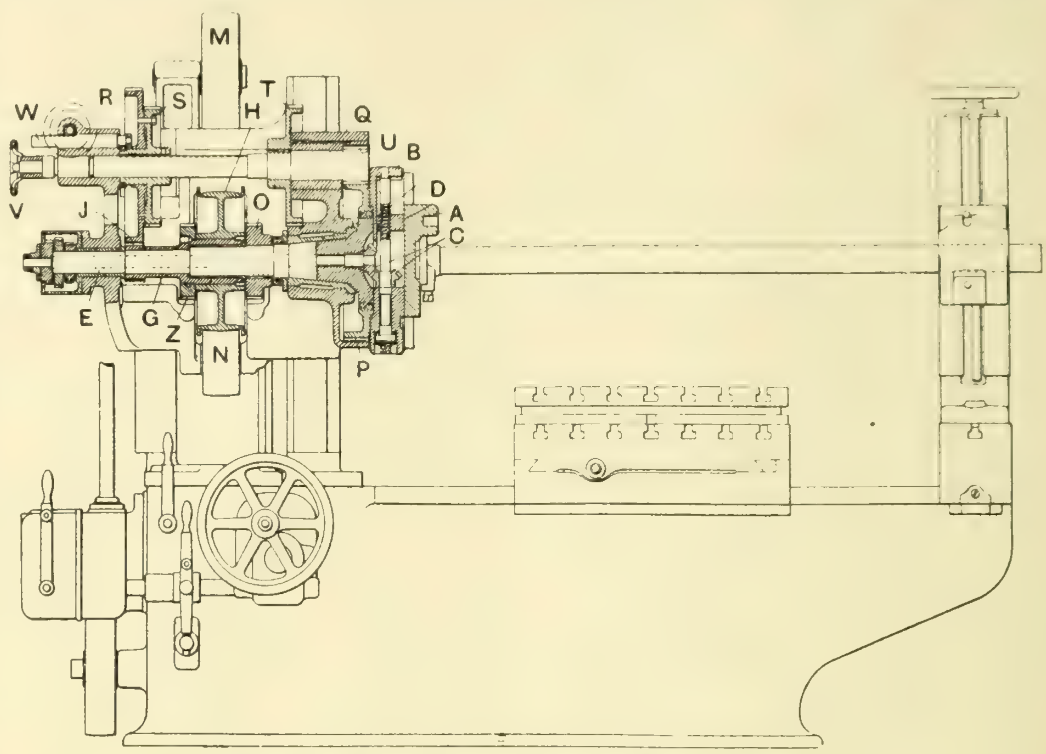


Fig. 1.—All Gear Drive for Boring and Facing Machines.

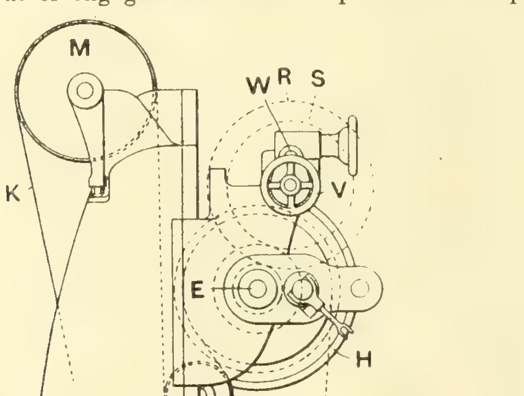


Fig. 2.—All Gear Drive for Boring and Facing Machines.

The slowest speeds of rotation of the face plate B are obtained from the belt pulley H by means of one or other of the spur wheels J and Z keyed on the sleeve G on the mandrel, the corresponding spur wheel R or S on the second shaft or spindle Q and the pinion U gearing with the spur wheel P on the operative end of the mandrel E. The highest speeds are obtained from the same pinions and spur wheels J, Z, R, and S, but the pinion U gearing with the facing head is slid out of action and simultaneously the spur wheel T upon the second spindle is moved into engagement with the pinion O by which the mandrel is now rotated.

The arrangement described provides for four speeds of the face plate B for one belt or chain speed, but by increasing the number of pinions on the sleeve G and the corresponding spur wheels on the second shaft Q the number of speeds can be increased. The belt or chain is driven from the main driving shaft of the machine through suitable change-speed gearing arranged in a gear box formed on the end of the machine and having a detachable cover so as to render the gears readily accessible.

Institution of Electrical Engineers: Yorkshire Local Section.—At the annual general meeting of the Yorkshire Local Section of the Institution of Electrical Engineers, held at Leeds on the 14th inst., the following officers were elected: Chairman, Mr. W. B. Woodhouse; vice-chairmen, Mr. H. H. Wright and Dr. R. Pohl; hon. secretary, Mr. John D. Bailie. For the four vacancies on the committee Messrs. W. M. Rogerson, H. A. Nevill, W. Lang, and F. J. Lowe were elected to take the places of Messrs. Barker, Bailie, Pohl, and Wilkinson, who retire by rotation from the committee.

Ghent Meeting of the Institute of Metals.—The annual autumn meeting of the Institute of Metals will this year, under the presidency of Prof. A. K. Huntington, Assoc.R.S.M., for the first time since the Institute's formation in 1908, be held on the Continent. It will take place in connection with the Ghent International Exhibition, the dates fixed being August 28th, 29th, and 30th. Among many important papers to be communicated will be the report of the Corrosion Committee. Details with regard to travelling arrangements, tickets at special rates, &c., will be announced later. Those desirous of attending the Ghent meeting of the Institute of Metals should send in their forms of application for membership to the Secretary of the Institute of Metals, Caxton House, Westminster, S.W., at the earliest possible moment, and not later than July 31st.

THE DESIGN OF VOLUTE CHAMBERS AND OF GUIDE-PASSAGES FOR CENTRIFUGAL PUMPS.†

BY PROF. A. H. GIBSON, D.SC.

(*Concluded from page 536*).

Determination of θ in Case of Pump.—As indicated by the triangle of velocities in Fig. 5, the relationships

$$f_2 \text{ Cot } \gamma = u_2 - w_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

$$f_2 = w_2 \tan \theta \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

theoretically apply at the discharging edge of each vane. Owing, however, to the fact that only those particles of water near to the driving face of the vane are discharged parallel to its tip, the real value of γ for the discharging stream is less than the vane angle γ, and consequently the tangential velocity w_2 is less than is indicated by equation (9) above. Experiments* show that if w_2 be calculated by this equation, its real value is kw_2, where k has the approximate values given in Table III.:—

TABLE III.

Number of Vanes.	Vane Angle γ. 20°	25°	30°	45°	60°	90°
6	0·80	0·79	0·78	0·77	0·76	0·75
8	0·85	0·84	0·83	0·82	0·81	0·79
10	0·90	0·89	0·88	0·87	0·86	0·84
12	0·95	0·94	0·93	0·92	0·90	0·87

Using the corrected value of w_2 in the formula $\tan \theta = \frac{f_2}{w_2}$ gives θ. This value of θ is probably slightly low, because experiments show that a dead water space which is not utilised for discharge is formed on the rear side of each vane, and that f_2 is in consequence somewhat greater than its calculated value. To counterbalance this, however, we have the fact that, owing to the gradual increase in the radius of the outer boundary of the chamber, the actual change of direction of the streams on impact is slightly less than the angle of impact θ. These effects, which are severally small, must to a large extent counterbalance each other, and calculations show that in any normal pump the error involved in the value of θ, by neglecting both of these, does not exceed 1°.

Experimental Results.—The large cost involved in modifying the volute chambers of a series of pumps has caused investigation of this question on the experimental side to be confined to a pump forming part of the equipment of the Hydraulic Laboratory at University College, Dundee. This has a single encased impeller; diameter, 13·5in.; breadth, 0·5in.; $\gamma = 30°$; having 10 vanes and designed to discharge 425 galls. per minute against 85ft. head, at 1,250 revs. per minute. The volute is of the usual circular section, as shown in Fig. 7. In order to reduce this cross-section, the spaces at S_1S_1 were filled in wholly or in part by plaster of Paris or plasticine (experiments *a*), or by Babbitt metal (*d*), while in experiments (*b*) and (*c*) the section was cut down by means of a continuous wooden strip bent to shape and filling up the space S_2. As thus modified, the areas of the volute at sections A, B, C, and D, Fig. 5 (respectively 90°, 180°, 270°, and 360° from the cut-water), were as follows:—

TABLE IV.

	Area of Volute (square inches) at Point A	B	C	D
Calculated best form	0·79	1·77	3·30	5·36
Original volute	1·1	2·6	4·1	5·6
Modification (*a*)	0·87	1·9	3·5	5·5
,, (*b*)	1·1	2·2	3·0	4·3
,, (*c*)	1·1	2·2	2·5	3·0
,, (*d*)	0·77	1·3	1·6	1·9

† Paper presented to the Institution of Mechanical Engineers.
* Bulletin, University of Wisconsin. 1907. No. 173.

Volute (*a*) thus forms a fair approximation to the calculated best form. Volute (*b*) and the original both differ from the ideal, but whereas the original is of better proportions towards the outlet D, (*b*) is of better form about B, but is restricted in area over the latter half of its length. This restriction is still further marked in (*c*), while in (*d*) the volute is considerably smaller throughout than should be the case according to the analysis.

The results of the efficiency tests with these volutes are shown in Fig. 8, and afford a satisfactory confirmation of the validity of the analysis. As compared with the original volute, modification (*a*) increases the maximum overall efficiency of the pump by approximately 6 per cent., while the greater the difference between the volute and that indicated by the theory, the smaller the efficiency.

Comparison between Modern Types of Volute and Those Designed by the Foregoing Analysis. In order to compare the proportions of the volute as commonly fitted, with those of the volute designed by the aid of this analysis, a few typical modern single chamber pumps by makers of repute have been examined. The essential dimensions, &c., of these are as in Table V., while the areas of the volutes at points A, B, C, D

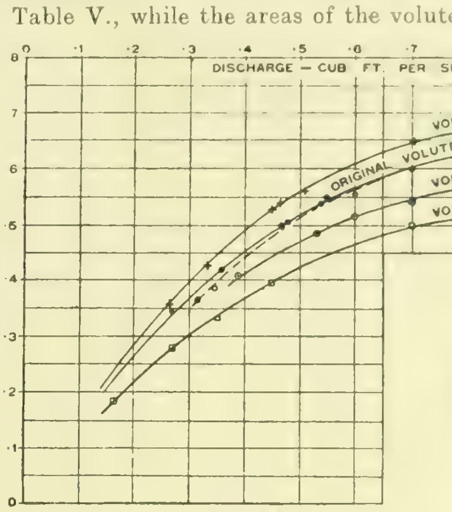


FIG. 8.

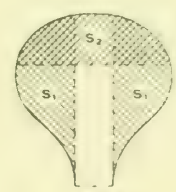


FIG. 7.

(Fig. 5), as measured and as calculated for the ideal volute, are as in Table VI.

TABLE V.

Pump.	Impeller. Diameter.	Breadth.	No. of Vanes.	Revolutions per Minute.	Discharge.	Head.	Calculated Values of γ	θ	f_2	u_2	w_2	$\frac{w_2^2}{2g}$	[illegible]
	in.	in.			gals. per min.	ft.							sq. in.
a	16·0	1·0	6	600	700	25	37	12° 6′	5·86	41·9	27·3	12·1	1·60
b	16·8	0·60	10	770	430	56	30	7° 51′	5·75	56·3	41·6	28·3	0·394
c	13·5	0·50	10	1250	425	85	30	8° 51′	8·12	73·5	52·2	45·4	0·308
c′	..	..	..	..	..	..	..	..	..	..	..	..	..

TABLE VI.

Pump.	Point (See Fig. 5). A Calculated.	A Measured.	B Calculated.	B Measured.	C Calculated.	C Measured.	D Calculated.	D Measured.	Maximum Efficiency
									per cent.
a	3·14	7·2	5·32	10·8	8·60	14·2	12·95	18·0	59·5
b	0·98	1·1	2·2	2·65	4·15	4·55	6·75	6·35	72·0
c	0·79	1·1	1·77	2·6	3·30	4·1	5·36	5·6	65·8
c′	,,	0·87	,,	1·90	,,	3·50	,,	5·5	70·5

It will be noted that the volutes are in every case larger than corresponds to maximum efficiency, and that the proportional difference is much more pronounced over the first than over the second half of the volute. With the exception of (*c* and *c′*), which is the pump tested by the author, the efficiencies given in the last column of Table VI. are taken from published records of tests by the makers.

Pump (*a*), which, because of its comparatively low head and low speed of rotation, should, if well designed, show a

high efficiency, is the least efficient of the series, and it will be noted that this is the pump in which there is the greatest difference between calculated and actual proportions of volute. Pump (b) on the other hand, shows the closest coincidence between the two sets of values, and in spite of its large number of vanes (10) shows the high efficiency of 72 per cent.

An analysis of the results of tests on (a) shows that while the rise in pressure outside the impeller would be approximately 5·2ft. ($0{\cdot}43\ \frac{v_2^2}{2g}$, Fig. 4) with the ideal volute, the actual rise was approximately 2·8ft., or only 54 per cent. of that available with the former chamber. The additional gain would increase the over-all efficiency of the pump by roughly 10 per cent. Similarly in (c) the rise in the ideal volute would be approximately 14ft. ($0{\cdot}31\ \frac{v_2^2}{2g}$,) as against 9ft. in the actual chamber. In this case the modification of the chamber would increase the efficiency by roughly 6 per cent.*

These examples sufficiently indicate the possibilities of improvement of the volute as usually constructed. It will be noted that these are in general too large for maximum efficiency, so that their modification would rather reduce than increase the cost of construction.

The figures of Table II. show very clearly that, however well designed a simple pump of this type may be, its efficiency cannot be expected to equal that of the turbine pump, in which,

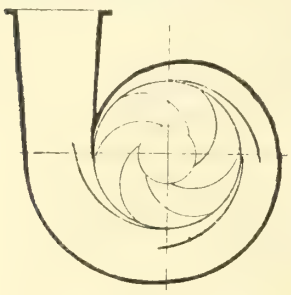


FIG. 9.

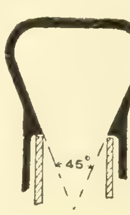


FIG. 10.

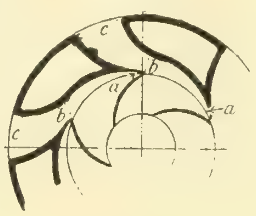


FIG. 11.

as far as conversion of energy is concerned, the effective number of vanes is equal to the number discharging into each of the guide-passages. This disadvantage, which is inherent to the type, might be minimised by the provision of a series of guides in the volute as shown in Fig. 9. If these were of sheet metal bent to shape and cast in position, such a construction would not add appreciably to the cost of the pump, and as the figures of Table II. show that in an 8-vaned pump the provision of three such guides (making four in all) would increase the possible conversion of energy by roughly 100 per cent., this method would appear to merit consideration, especially for large pumps operating under fairly constant conditions.

Best Form of Section for Volute.—The question as to what is the best form of section for the volute is of importance. The various filaments, after entering the volute, trace out a mean path approximately parallel to its outer boundary, so that the net deflection of the discharging streams and therefore θ will be least when the rate of increase in diameter of the volute is a maximum, that is, when the chamber has parallel sides of the same width as the impeller. Such a chamber would have the advantage that its interior surface could readily be machined or smoothly finished off to reduce friction, while it would be a simple matter to modify patterns to suit the varying requirements of different pumps. Furthermore, the addition of guide-vanes would become a comparatively simple matter. On the other hand, with small pumps a chamber of this form would have a comparatively small hydraulic mean depth, and its friction losses would on this account tend to be somewhat high.

Failing this, the experiments on diverging passages, to which reference has been made, indicate that the form of section shown in Fig. 10, with straight sides inclined outwards at about 22½° (total included angle 45°), should give good results in the conversion of kinetic into pressure energy in the average pump. This form of section enables the outflowing streams to diverge at about the best angle when moving with their highest velocity, and has the further advantage that the interior surfaces can be smoothly finished off with little difficulty.

Whatever section is used it will be found that with the best areas the velocity in the volute is usually from three to four times that permissible for flow through the discharge pipes, and in order to enable as much of the kinetic energy of this flow to be utilised as possible, connection between the volute chamber and the discharge pipe should be made by a taper pipe having walls diverging at about 6°, Fig. 5.

Design of Guide-Passages for Turbine Pumps.—In a turbine pump, Fig. 11, the portion of each guide passage from a to b is to all intents a portion of a volute, and the losses between these points will be the same as in the same portion of an ordinary volute. For minimum loss the area at any point must therefore be calculated as already described. The possibilities as regards the conversion of kinetic to pressure energy in a rectangular passage with one pair of divergent walls are, however, somewhat less than in a corresponding circular pipe, and with the best angle of divergence the loss is about $0{\cdot}20\ \frac{(v_2 - v_1)^2}{2g}$ instead of $0{\cdot}15\ \frac{(v_2 - v_1)^2}{2g}$ as in the latter case.* Taking this into account the value of m in formula (7) for best results is given by

$$m = 1{\cdot}10 + 0{\cdot}20\, n^2 + 0{\cdot}0265\, n\theta,$$

where n and θ have the same meanings as before.

Under these circumstances Table VII. shows what proportion of the kinetic energy of discharge may be converted into pressure energy with the best form of guide passages.

TABLE VII.

θ	Number of Impeller-Vanes to each Guide-Vane.					
	1	2	3	4	6	8
5°	0·86	0·74	0·63	0·54	0·43	0·36
7½°	0·83	0·72	0·61	0·53	0·42	0·35
10°	0·81	0·70	0·60	0·52	0·41	0·34
15°	0·77	0·66	0·56	0·49	0·38	0·32

From this table it appears that if θ is, say, 7½°, the possible conversion of energy in the guide passages is 83 per cent. if the numbers of guide and impeller vanes are equal, while with twice as many impeller as guide vanes the proportion falls to 72 per cent., and with three times as many, to 61 per cent. As, with an eight-vaned single pump, the proportion is under 40 per cent., when both pumps are well designed and working under equally favourable conditions the turbine pump should utilise double the kinetic energy of discharge, and as this amounts to some 40 per cent. of the total energy of discharge, the efficiency of the turbine pump should be some 15 per cent. greater than that of the simple pump with no guide vanes. As the latter type of pump gives efficiencies up to 75 per cent. there would appear to be no reason why the turbine pump, even when every allowance is made for additional losses in connecting passages, should not readily attain efficiencies exceeding 85 per cent. Some pumps do, it is true, achieve efficiencies approximating this, but the great majority are only slightly more efficient than the best of the simple pumps.

An examination of a number of modern high-lift turbine pumps indicates that this is partly due to the bad design of the volute portion of the guide passages and partly to the fact that an insufficient number of guide vanes is provided. The following are typical examples of triple or quadruple pumps lifting against heads of between 75ft. and 85ft. in each chamber:—

TABLE VIII.

Pump.	Impeller.		No. of Vanes in		Area of Guide Passages at (b), Fig. 11.		Maximum Efficiency.
	Diameter.	Breadth.	Impeller.	Guide Ring	Measured.	Calculated for Best Results.	
	ins.	ins.					
a	15	1·5	6	5	2·60	2·63	80
b	26	2·0	6	5	7·0	6·00	75
c	23	2·0	9	4	8·0	5·04	70

* Confirmed by the tests (see Fig. 8).

*Trans., Royal Society of Edinburgh, 1911, Vol. xlviii., Part I., page 104.

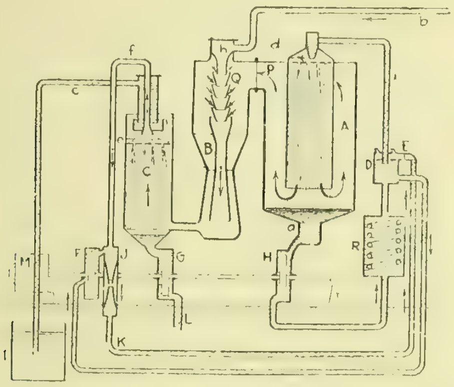
Of these *a* is by a continental maker whose pumps are deservedly famous for high-working efficiency. In this case the passages are of good section but slightly small, while the number of impeller vanes is low and that of guide vanes approximates to that of impeller vanes. Pump *b* has the same number of vanes, but the areas of the passages are consistently too great, while in *c* not only is the number of guide vanes smaller but that of impeller vanes is higher, while the areas are much too great. Tests by the author of a pump similar to, but slightly smaller than, *c* gave a maximum efficiency of only 67 per cent.

The investigation indicates that the possibilities of improvement of the average turbine pump are as great as are those of the simple pump. In such a pump the area of the passage from *a* to *b*, Fig. 11, should be calculated as already described. From *b* to *c* in the expanding portion of the passage the sides should diverge at an angle of 12°, since this is the angle which gives minimum loss of energy in such a passage of rectangular section.

WESTINGHOUSE-LEBLANC WATER VAPOUR REFRIGERATING MACHINE.

BY H. J. MACINTIRE.

MECHANICAL refrigeration has shown great progress in the last decade and now is used in almost every industry where rapid cooling is required. A number of refrigerants have been used



DIAGRAMMATIC SECTIONAL VIEW OF WESTINGHOUSE-LEBLANC WATER VAPOUR REFRIGERATING MACHINE.

for mechanically securing low temperatures. In the early days air was employed, the approximate adiabatic expansion of which gave the desired low temperature. The air machine, however, is bulky and has a low efficiency, so that recourse is made to the use of a vapour of suitable boiling temperature. Of the number of theoretically possible refrigerating vapours carbon dioxide, sulphur dioxide, and ammonia alone are used. In America, ammonia is employed for about 95 per cent. of the total refrigeration, whereas, in England, France, and Germany, carbon dioxide is used to a much greater extent.

Refrigeration on board ship, in mines, hotels and other confined quarters, where the liberation of a noxious gas would be serious, makes the problem of selecting an appropriate refrigerant of even greater importance. None of the three vapours mentioned are innocuous to man, although carbon dioxide is most nearly so. However, the pressures carried with this last, frequently 1,000lbs. to 1,200lbs. per square inch, are excessive and explosions are not unknown. This danger is recognised in the French Navy, which has limited the size of the units used in their ships. The U.S. Navy is still using a dense-air machine which carries a suction-line pressure of 65lbs. gauge, the gas being used continuously, but these machines are never built in any but very small sizes and trouble due to freezing of the lubricating oil is encountered daily.

The most logical medium to use, the one costing least and the one which would be perfectly harmless, is water vapour. The difficult problem here is, however, in caring for the vast increase in the specific volume of steam at low temperatures; at 50° it is 1,702 cub. ft., at 40° it is 2,438 cub. ft., and at 32° it is 3,294 cub. ft. per pound of steam. If a compressor with a piston were used for compressing the vapour the necessary displacement of the machine per pound of vapour would have to be absurdly great. Fortunately, the same end may be obtained with high speed rotary apparatus, or its equivalent, as is shown in the design of the Westinghouse Leblanc water power machine.

The accompanying figure shows diagrammatically the arrangement of this machine. At R are the refrigerating coils which may be arranged to carry the cooling agent within them in the usual manner, or to allow the brine or cold water to fall in the form of a spray in contact with the air to be cooled. In the latter case some moisture is absorbed from the air, which partially neutralises the loss of vapour in the evaporating chamber A. The warm brine now passes into the reservoir D which is subject to atmospheric pressure, and is then siphoned into the evaporator A, into which it falls in the form of a fine spray, after having passed the perforated plate *d*. The jet-condenser chamber is at C, the condensing water coming in from the cold-water supply I through a perforated plate *e* at the top of C. The condensing water and condensate are removed by means of a turbine-type pump G and the air and water vapour by means of the rotary pump with water pistons at F and J. A vacuum of 1lb. absolute may be obtained at C with cooling water of usual temperature, and in order to obtain $\frac{1}{10}$lb. absolute in A (corresponding to an evaporating temperature of 28-30° Fah.) work must be done on the vapour from A to compress it to the pressure in C. This is accomplished by means of the ejector cones Q, through which steam passes at high velocity, dragging with it the vapour evaporated in A. Either high-pressure or exhaust steam may be used, and in the latter case the electric motor M is replaced by a small steam turbine, and the pipe *b* conveys the exhaust to the chamber B. As shown, all the pump motors are on the same shaft. The level of the reservoir D is maintained constant by means of some kind of float and valve, which admits water at the temperature of the supply I.

Although temperatures of 32° Fah. and lower may be obtained, its special sphere of usefulness is for temperatures of from 35° to 50°. With these latter temperatures, the economy is high, being about 400 B.T.U. of refrigeration per pound of steam supplied to the ejectors, whereas only about 200 B.T.U. is obtained at a refrigerating temperature of 25° Fah. As air cooling in auditoriums, banks, hotels, chocolate factories, &c., seldom requires temperatures lower than 50°, and as the installation has no element of danger on account of the harmless refrigerant, a field will probably soon open for it along these lines.

So far little information is available about the space required, but it will not be greater than that necessary for the ammonia compressor and condenser. The design is so simple that the first cost will be small and, for the uses cited, no brine should be necessary as the temperatures are safely above 32° Fah. There is no practical limit of size to this machine, the largest in Europe being about 350 tons, and in America about 200 tons of refrigeration.

In comparing the relative efficiencies of the water vapour and ammonia machines, only approximate values can be given, as too many specific factors come in for a general statement. Roughly, the horse-power of the ammonia compressor per ton of refrigeration varies from 0·5 to 1·2 or more, which would correspond to from 15lbs. to 30lbs. of steam per ton of refrigeration, or to from about 300 B.Th.U. to 600 B.Th.U. per ton per minute, a value which is nearly, if not quite, the economy of the water-vapour machine. Considering (1) that the modern small impulse steam turbine and centrifugal pump may be run for days without attention, the cost of maintenance and operation being reduced accordingly; and (2) that the element of danger is lowered to a minimum, then this water-vapour machine would seem to compare favourably in economy with older types of refrigerating machines.—"Engineering News."

Submarine Bells for Liners.—As a result of a series of successful trials in submarine signalling from steamers, the North German Lloyd have decided to equip a number of their steamers with submarine bells of a similar type to those fitted to lightships. The advantage to be derived from the possession of these bells is that the steamers so equipped will not only receive the signals from the regular warning stations, but will themselves be able to send out sound signals, so that in the event of a vessel being in distress in a fog its position could be easily located and the vessel found by any other ship fitted with a submarine receiving apparatus.

A NEW FORM OF ELECTRICALLY-DRIVEN TWO-HIGH CONTINUOUS-RUNNING REVERSING MILL.*

BY ANDREW LAMBERTON.

DURING the past few years the attention of engineers and steelworks owners has been closely directed to the problem of the economical driving of rolling mills, which have in the past in the majority of cases been far from satisfactory in this respect, and although the subject is surrounded with many difficulties very satisfactory progress has been made and the way cleared for further advance.

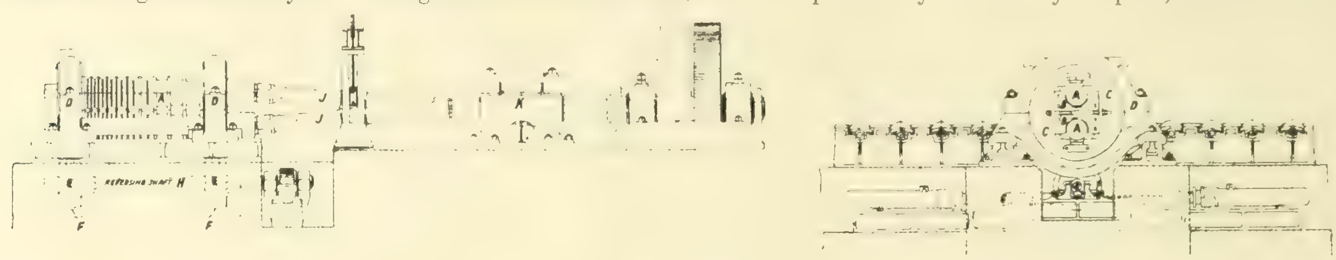
As was to be expected, electricity has been much in evidence, and great credit is due to those who have been pioneers in this respect for the ingenuity they have displayed, and the large measure of success which has attended their efforts. The day, however, has not yet arrived when it can be claimed that by the universal adoption of electricity as the motive power for driving rolling mills in iron and steelworks the highest economy in running costs can be attained; and every proposed installation of such machinery would require to be most carefully considered in relation to the existing conditions, and decided upon its true merits.

Speaking generally, where steelworks are associated with blastfurnaces, and perhaps also coking ovens, and an abundant supply of surplus gas is available for producing electric current at a low cost, electrical driving of such mills is clearly indicated; and the question before the engineer then becomes one of the economical design of such plant, both as regards first cost of installation and economical performance. The greatest difficulty is met with in dealing with reversing mills of the two-high type, where the rolls have to be reversed at each pass, and when these mills are of large size the electrical plant is extremely costly, the reversing mill motors necessary being from 10,000 b.h.p. to 15,000 b.h.p., due to their having to start from rest under full load at each reversal.

We are all familiar with the Ilgner system of driving such mills, first introduced in Germany, and with which Messrs. Siemens Bros., of London, have, in this country, been closely identified; and several very interesting papers have been submitted by Mr. Ablett, of that firm, describing such installations. The high initial cost, however, seems to militate against the general adoption of the Ilgner system in this country, as British steel-makers seem very slow to adopt it; and it is noteworthy that two of the most recently erected steelworks in this country, in both of which blastfurnaces and coke ovens exist and an ample supply of free gas is thereby available, although using electricity for every possible purpose, have not adopted it for driving their reversing mills, which seems to indicate that the high initial cost and other considerations have made it clear that this was not in these cases the most economical when all the conditions were fully considered.

All engineers may be said to be in agreement, that where rolling mills can be driven by a constant-running motor associated with a heavy flywheel to take the peak loads of rolling, electrical driving is to be preferred, provided, of course, that the cost of current be low enough. Look for a moment at some of the main considerations that arise in connection with the adoption of electricity for driving bar, rail, and section rolling mills.

For small mills rolling light sections and bars, which can be fed to the mills by hand, the three-high continuous-running mill is practically universally adopted, and in such cases the driving of these mills by a continuous-running electric motor leaves nothing to be desired. For larger mills rolling bars and sections of heavier type which cannot be fed by hand, and where live roller feeding tables and mechanical manipulators are therefore necessary, the three-high type of mill is not so popular in this country, although it must be admitted that on the Continent and in America this type of mill is quite commonly used even for heavy sections. The main objections, however, are the complicated live roller tables which require to rise and fall at each pass, and the increased difficulty of manipulating the bars on these rising and falling tables. There is also the further difficulty of the exact setting of three rolls to give accurate sections, together with the multiplication of the guides and guards required in this system. These considerations have caused steel-makers in this country to prefer the two-high type of reversing mill for such heavy bars and sections, even although the driving of such mills by reversing steam engines is less economical.



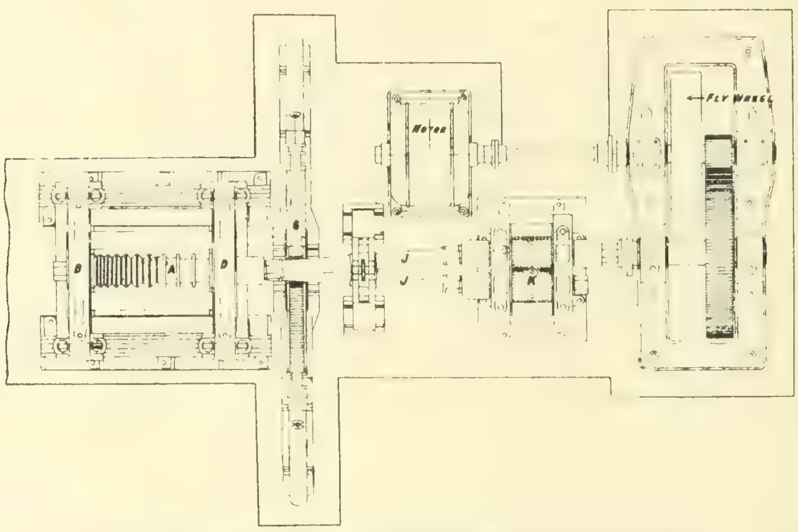


FIG. 1.—GENERAL ARRANGEMENT OF TWO-HIGH CONTINUOUS-RUNNING REVERSING MILL.

This being so, it occurred to the author that if two-high section rolling mills could be designed so as to be capable of being driven by a continuous-running electric motor, and at the same time give the necessary reversals to the bar at each pass, this would go a long way to meet the difficulties referred to, as the ease of setting the rolls in the two-high mill, and the simplicity of the roller tables being fixed instead of moving, would be conserved, and the large and very costly reversing motor rendered unnecessary. The following is a short description of the method by which this is accomplished:—

The root idea of the new system is that, if in a mill with two rolls, arrangements can be made to make the bottom roll the top roll, and vice versâ, then at each reversal of the position of these rolls there will be a pass in the opposite direction. If then a pair of rolls be mounted in circular gables which are free to rotate in fixed frames or housings, this will afford a continuous-running two-high mill, which gives reversals at each pass, on the gables being rotated through an angle of 180°—half a revolution.

Referring to Fig. 1, the two rolls A are mounted in the usual form of chocks B contained in the circular gables C, which gables are free to rotate in the fixed frames or housings D. In order to make the turning of the gables easy, these are carried on broad revolving anti-friction rollers E placed immediately under the gables, and carrying

* Paper presented at the annual meeting of the Iron and Steel Institute, May, 1913.

the weight of same. These anti-friction rollers have part of their breadth formed into a spur pinion F which gears with corresponding teeth in the rotating gables. By means of a hydraulically-operated rack G gearing into pinion on the bottom roller shaft H, the rotation of the gables is quickly effected, the time taken being only 3 secs. to 5 secs., and the stroke of the hydraulic rams is just sufficient to bring the rolls to their exact position at each reversal. To provide for the alternate change in the position of the top and bottom roll, the driving spindles J, conveying the power from the mill pinions K to the rolls A, are disposed in the manner shown on the drawing, and the weight of these spindles is borne up in their centre by a balanced carrying gear, the weight of the descending spindle balancing that of the ascending spindle at each reversal. It will be noted that the mill pinions are placed side by side, and not superposed as is usual, as this side-by-side arrangement reduces the angle on the spindles during reversals.

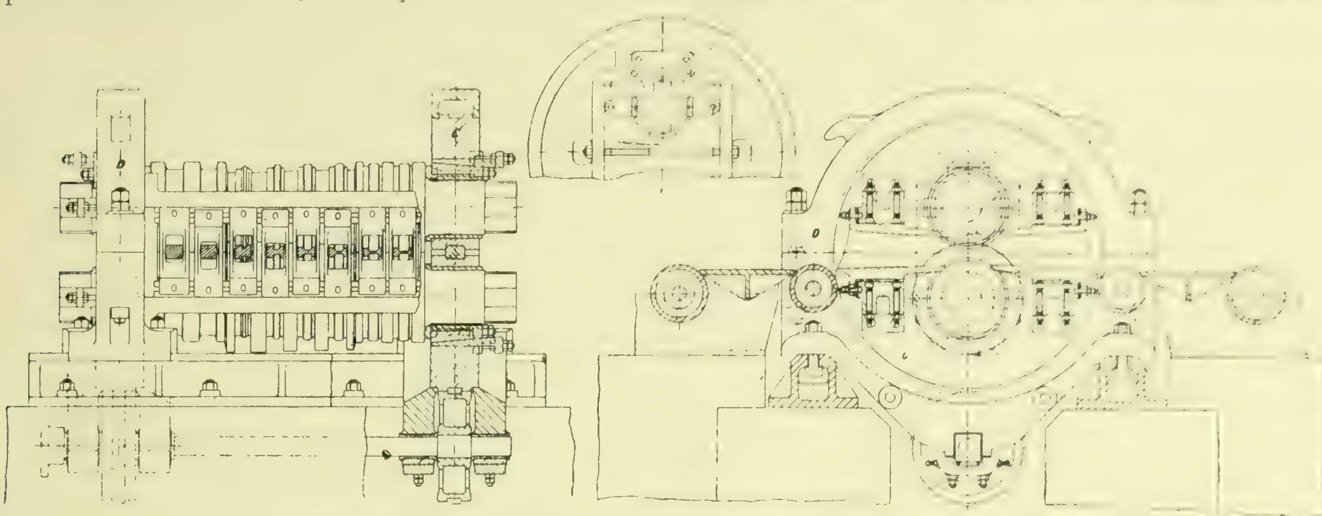


FIG. 2.—ENLARGED VIEW OF ROTATING GABLES (C) AND FIXED FRAMES (D).

With regard to the motor, driving gear, and flywheel, these are so well understood as to require no description, except to observe that by the employment of a high-speed continuous-running motor the size and cost of such motor is reduced to a minimum; and as the flywheel takes the peaks of the rolling loads, the highest economy in operation results.

In Fig. 2 the revolving gables with the fixed frames are shown to a larger scale, and the guides and guards for rail rolling are also shown in position.

An interesting point to observe is that in rolling rails and sections in the ordinary type of two-high mill, it is necessary to turn the bar upside down to prevent the formation of fins, but this is entirely obviated in this new design of mill, because the rolls take alternately top and bottom position, and finning is thereby corrected, so that the turning of the bar upside down is rendered unnecessary and the operations of rolling simplified.

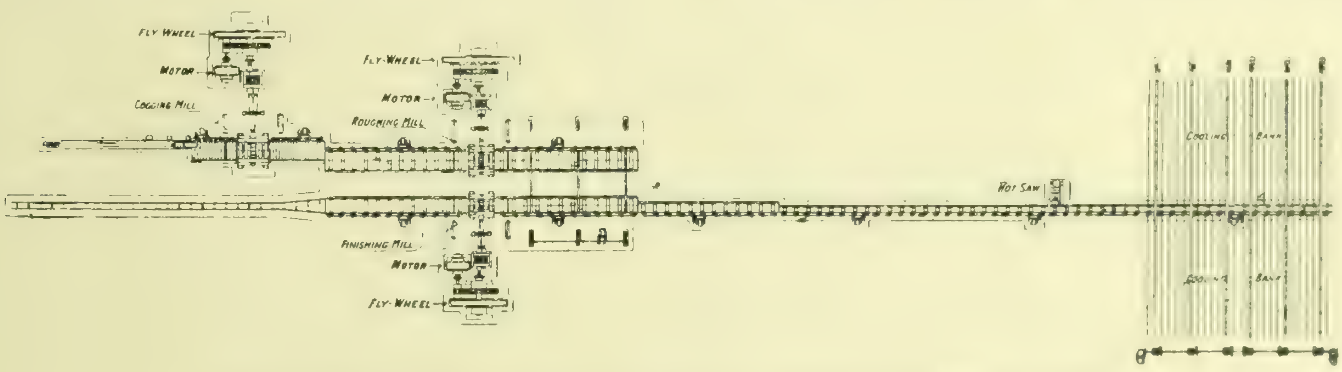


FIG. 3.—GENERAL ARRANGEMENT OF RAIL-ROLLING PLANT FOR A PRODUCTION OF 5,000 TONS PER WEEK.

In Fig. 3 is shown the general lay-out of a rail-rolling mill plant on this new system, capable of an output of 5,000 tons per week. It will be observed that three distinct mills are shown: (1) A cogging mill taking the ingot and reducing it to a bloom; (2) a roughing mill to reduce this bloom to a roughly formed rail; and (3) a finishing mill to finish the rail to the required section.

These mills are all of the same continuous-running reversing type, the rolls having fixed draughts, so that there is no screwing-down gear required. The live roller tables are all fixed tables of the simplest form, and the manipulation of the ingots at the cogging mill, the blooms at the roughing mill, and the rails at the finishing mill is of the simplest character. High-speed continuous-running electric motors with suitable flywheels are used to drive each of these mills, and these motors are all of most reliable type and highest efficiency. The author ventures to think that in such an installation a very high efficiency would be obtained, with the minimum initial cost.

The first mill of this new type is now in course of construction, and will be put to work in a large steelworks in England in the early summer, when the results in every-day operation will be available; and the author will be glad to give these results in a subsequent communication. There is, however, another side to this problem of the economical rolling of steel products, which, although it concerns the engineer less than the one just considered, is of the utmost importance to the steelworks owner, and cannot therefore be overlooked.

It is well known that to obtain the highest economy from any rolling plant the maximum capacity of such plant must be realised, for if, say, in a plant of 5,000 tons capacity per week only an average of 3,000 tons is actually obtained, the cost per ton of production on this reduced quantity would be much higher than would have been the case had the maximum output been secured; and it is to be feared that this condition of things is all too characteristic of the rolling mills in this country.

Let us look at some of the causes which go to explain this shortage in output: First, and probably the greatest, are the constant fluctuations in trade, in sympathy with which the demand rises and falls; and second, the fact that the total capacity of existing plants in this country is now much greater than the average demand for their products, with the result that the total quantity of the work placed is split up into numerous small orders, that rarely ever afford an oppor-

tunity for a lengthened run on the same section, by which alone a maximum output is possible. This also results in constant changing of rolls for the different sections required, incurring large expense and very great loss of time.

Under such conditions as these the output capacity of mills cannot possibly be even approximately reached, and the cost of production is thereby chronically excessive, and reacts upon and checks demand; and so it would appear that our steel-makers seem to be within a vicious circle, where limited demand results in high cost of production, and where high cost of production again causes limited demand; and this is a situation sufficiently serious to claim the earnest attention of all those directly interested. Not much comfort or satisfaction is to be got from those who will tell us that this is clearly a case of the survival of the fittest and the withdrawal of the vanquished from the field. Is there, however, no remedy at all for such a state of matters? Remedies have been proposed, to which the author dare not allude in this place, but there is one which is so safely outside the pale of politics that no apology is necessary in referring to it—this is "specialisation."

We are all familiar with the saying, "It is a wise farmer who looks over his neighbour's fence," and those of us who have visited America and Germany and seen the steelworks in these countries could not fail to have been impressed with the constant endeavour put forth to carry out this principle of specialisation to the fullest extent in all their operations; and this for the sole purpose of enabling them to produce cheaply, and consequently to keep their plant running to its fullest capacity, in the knowledge that the more they produce the cheaper they produce

Hence we see continuous billet rolling mills working all the time on billets alone, and producing these in quantity far above, and at a cost far below, what can be done in this country. The same principle is carried through in all their rolling operations, the orders received at head-quarters being carefully classified and sent to the mills specially designed for producing the sections required, and large economies being thereby effected. In Germany the Verband, controlling a number of the largest works, carries out this same method, and years of experience have now proved the great value of the system.

At the present time the steelworks all over the world are practically full of work, so that the British steel-maker is not seriously affected by American and German competition, but the inevitable ebb in the tide of prosperity is sure to set in, and then the struggle for our share of the business of the world will certainly be keener than we have ever yet experienced. To meet this our steel-makers will have a very serious and difficult problem to face, as the conditions in this country are admittedly widely different to those in America and Germany.

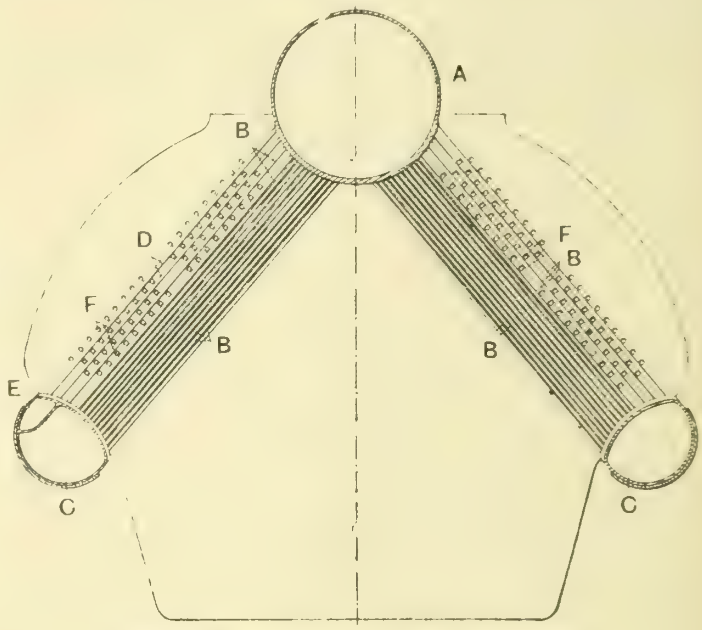
In whatever way the matter may be dealt with, the value of this system of specialisation in design of mills, and classification and selection in the work rolled in these mills, which have proved beyond doubt so beneficial wherever they have been systematically followed, cannot be ignored, and every improvement that can be devised tending to increase the efficiency and simplicity in operation of such mill plants must constantly engage the attention of the engineer, if we are to hold our own against the very formidable opponents who so strenuously assail our position, and who enjoy advantages in regard to our markets here which are unfortunately denied to us by them.

Should the new methods described in this short paper prove in some degree instrumental in attaining higher economy in rolling-mill practice, or be assistant to others who may be working on this important problem, the author will feel amply compensated for any little trouble he has undertaken in this modest effort towards improvement on existing methods.

Oil for the British Navy. — The Admiralty have given instructions for another oil-carrying vessel to be laid down at Pembroke Dockyard, which will raise to 10 the number of such vessels built or building for the Navy. Altogether the supply of oil fuel to the fleet will cost over a million sterling in the current financial year.

COMBINED WATER-TUBE BOILER AND SUPERHEATER.

THE accompanying illustration shows a design of water-tube boiler having superheating tubes arranged in single rows intermeshing with some of the water heating tubes. The arrangement, which is the joint invention of the Hon. Sir Charles A. Parsons, Heaton Works, Newcastle-on-Tyne, and Mr. S. S. Cook, has been designed with a view to avoid the excessive heating of the superheater tubes when for any reason such as a reduction of power or the sudden shutting down of the engines, the flow of steam through them is reduced or stopped altogether, while under normal conditions, an efficient superheat is obtained. The boiler is of usual construction having a steam drum A connected by means of water tubes B to two lower water drums C, between which the fire grate is arranged. On the left-hand side of the figure are shown additional tubes D connecting the steam drum A with a chamber E within the lower drum C, these additional tubes being provided for the purpose of preheating the boiler feed water before it is passed into the drums C and evaporated in the water tubes B. The necessary degree of superheat is imparted to the steam by



COMBINED WATER TUBE BOILER AND SUPERHEATER

passing the same from the steam drum A through a series of superheating tubes F arranged transversely to the tubes B. The superheating tubes F, it will be seen, are intermeshed in single rows entirely with the tubes B, as shown on the right-hand side of the figure or partly with the tubes B, and partly with the tubes D, as shown on the left-hand side. The tubes F are not only intermeshed with the tubes B and D, but are arranged in close proximity thereto, and in this way the mutual heat radiation between the tubes prevents the superheating tubes F from attaining an excessive temperature when the flow of steam through them is diminished or entirely discontinued. Under normal conditions of working this mutual radiation in no way diminishes the efficiency of any of the tubes B, D, or F, but on the reduction of power or shutting down of the plant which is supplied with steam by the boiler, the radiation between the superheating tubes F and the water-containing tubes B and D will be paramount in determining the temperature of the superheating tubes.

Electrification of the North-eastern Line.—The North-eastern Railway Company have been considering the extensive electrification of their lines in the mid-Durham coalfield, and a 20-mile section stretching from Shildon (near Bishop Auckland), where there are very extensive coal sidings, to Newport (near Middlesbrough) has been selected for the start. The overhead system is to be used where possible, but conductor rails will have to be resorted to in some places. The locomotives will be capable of drawing 1,400 tons on the level at an average speed of 25 miles an hour.

ON PHASE-ADVANCING.*

BY DR. GISBERT KAPP.

IF the current sent out from a power-house has a lagging component, this may be compensated and the power factor brought to unity by connecting to the circuit some apparatus taking a leading current. A well-known form of such apparatus is an over-excited synchronous motor, and it has also been suggested to use an electrostatic condenser for this purpose. Whichever apparatus is used the improvement takes place from the generator up to the point of attachment, but not beyond. The apparatus must therefore not be installed in the power-house, for there it would only relieve the generators of wattless current, and not the line. Apart from this imperfection, it can easily be shown that this method is wasteful both in capital outlay and in running cost. In capital outlay because the volt-ampere capacity of a generator and rotary condenser is greater than that of a generator made large enough to give both components of the current, and in running cost because some power is lost in running the rotary condenser.

Let E I be the output required from the generator; then E I must also be its volt-ampere capacity if no phase advancer is used. If such an apparatus is used, then the output from the generator need only be $E I \cos\phi$. The volt-ampere capacity of the rotary condenser will be the product of $I \sin\phi$ and the voltage to which it must be excited. This is about 30 per cent. more than the busbar voltage, so that the amount of dynamic machinery is in the two cases respectively E I and $E I (1 \cdot 3 \sin\phi + \cos\phi)$; whilst the available power is reduced by the loss in the rotary condenser, resulting in a slight lowering of the efficiency. The expression—

$$1 \cdot 3 \sin\phi + \cos\phi$$

shows the proportional increase in the amount of electrical machinery over the case where a generator is large enough to give both components.

The following table shows this proportion for various power factors, and also the loss in the rotary condenser. The latter figure is calculated on the assumption that all losses are covered by an allowance of 4 per cent. on the volt-ampere capacity of the rotary condenser.

Power factor	1	0·95	0·90	0·85	0·80	0·75	0·70
$1 \cdot 3 \sin\phi \times \cos\phi$......	1	1·35	1·46	1·53	1·58	1·61	1·62
Loss in per cent. of power generated	0	1·7	2·50	3·20	3·90	4·30	5·20

Thus, to compensate for a power factor of 0·8 by a rotary condenser the cost of the electrical plant will be increased by 60 per cent. over a generator designed large enough for this power factor—and the cost of the steam plant and the expenses for power will both be increased by about 4 per cent. Obviously it is a wrong policy to install the phase advancer side by side with the generator.

The same reasoning applies to an electrostatic condenser. The losses would probably be a little smaller, but to save 20 per cent. of generator volt-amperes we should have to put in 75 per cent. of condenser volt-amperes, obviously the reverse of a commercial proposition.

We may thus dismiss at once the idea of installing any kind of phase-advancing apparatus in the power-house, and turn to the only practical plan of putting such apparatus at the end of the line or on the customer's premises.

Here we may distinguish two cases. First the reduction of the phase angle of the installation as a whole without any change in the power factors of individual motors or other consuming devices; and secondly, the increase of the power factor of individual motors. The first case is obviously the only possible one if electrostatic condensers are to be used, and it is also the only possible solution with rotary condensers if the existing motors, either because of small size or special type, do not lend themselves to the application of individual phase advancers.

In the second case the advancement in phase of the current of a few large motors may be carried beyond what is required to bring their power factors individually to unity, so that these large motors are compelled to take a leading current which will make up to some extent for the lagging current taken by the small motors. It will be convenient to treat the two cases separately.

* Paper read before the Institution of Electrical Engineers.

I. Phase Advancement of the Supply System as a Whole.

At first sight this would appear the best policy, because in no way does it interfere with the existing arrangements of the customers of the power company. A little consideration of the general problem, however, soon leads to the conviction that this plan is too expensive for general adoption and can only be justified if the cost of the line has a preponderating influence. It is the only possible method where the consuming devices are squirrel-cage motors, arc lamps, induction furnaces, and similar appliances; and then it becomes a question whether it will be more profitable to put in a phase advancer or to lay an additional line and install additional generators, if the plant must be extended.

Each case must be studied on its merits; but to obtain at least an approximate view of the economic conditions involved, we may consider the case of a group of small motors taking together at peak time 100 kw. at a power factor of 0·7. This is not too low an estimate, for whilst a few of the motors may be working fully loaded with something like 0·85 power factor, a good many will be underloaded, so that the power factor of the group as a whole cannot be expected to have a higher value than 0·7.

Now suppose that this installation must be extended by the addition of similar motors. The line is loaded to its full current capacity. Any additional power required for the new

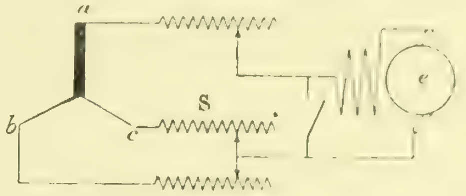


FIG. 2

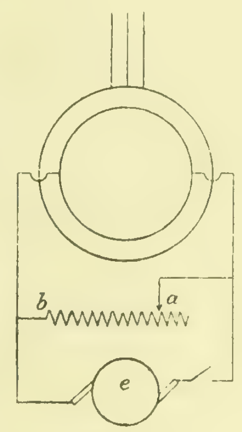


FIG. 1

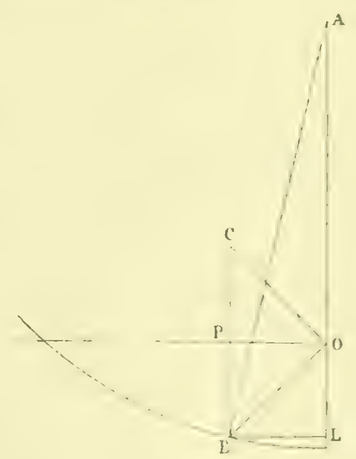


FIG. 3.

motors must therefore either be supplied over a new line or the power-carrying capacity of the old line must be increased by improving the power factor. It may be assumed that the steam plant has the required margin of power, and since the current is not increased the generators will also be able to give the additional power. To fix our ideas, let us assume that the line loss before the enlargement of the installation, when the power factor was 0·7, was 10 per cent. of the power delivered, or 10 kw., and that this loss shall not be exceeded when a phase advancer is installed. This means that the output of the generator, defined as so many volt-amperes, will remain the same. In our case this output is 153 k.v.a. The gain in saleable power will depend on the amount of phase advancement, but cannot exceed the value corresponding to unity power factor. Allowing 4 per cent. of the volt-ampere capacity of the idle running motor to cover its losses, the net saleable power before and after the installation of the phase advancer is given in the following table:—

Power factor	0·70	0·80	0·85	0·90	0·95	1
Saleable kw.	100	113	120	125	131	136
Efficiency	0·91	0·91	0·90	0·90	0·90	0·89
K.v.a. of idle running motor	0	40	61	85	116	180
K.v.a. required for each additional saleable kw.	—	3	3	3·4	3·7	5

Since the phase advancer is a synchronous motor it requires an exciter, starter, and synchroniser. The cost of such a machine with its adjuncts would hardly be less, and may be more, than £2 per k.v.a. capacity, so that if new motors are installed taking at peak time an additional 25 kw. at 0·7 power factor, this would entail an expenditure of about £180 for the phase advancer and a sacrifice of 1 per cent. in efficiency of transmission from generator to motors. If the additional power required amounts to the possible maximum at unity power factor, namely, 36 kw., the additional expenditure would be £380 and the efficiency would be lowered by 2 per cent. Thus every additional kilowatt set free for sale is obtained at a capital outlay of from £7 to £10.

The financial position is not improved by replacing the dynamic machine by an electrostatic condenser. In the discussion on Prof. Miles Walker's recent paper* Mr. A. W. Ashton quoted £2·8 per k.v.a. as the cost of condensers, and in a letter to the Press this was afterwards corrected to £1·9 for a frequency of 50. For power transmission a lower frequency is desirable, and then the cost of condensers is proportionately increased. The static condenser can therefore in point of cost hardly compete with the dynamic condenser. The fact that it requires no attention and has a slightly lower loss is more than counterbalanced by its as yet experimental nature. We know that a motor can run for any length of time with perfect reliability, but we do not as yet know how a condenser will behave if it is connected to the line and left there during an unlimited period.

In what follows, the author limits himself to the study of phase advancement by dynamic machinery.

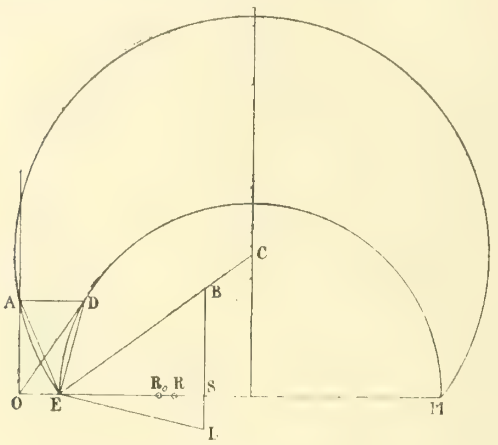


FIG. 4.

Whether the expenditure of from £7 to £10 per kilowatt of additional saleable power is a commercial proposition cannot be decided generally. If the line were very long and expensive it might pay, but at any rate a less costly solution would be preferable. Such a solution is provided in the second case, viz.:—

II. Phase Advancement Applied to Individual Motors.—Since in this case the dynamic condenser is not only used as a phase advancer, but is also doing useful work as a motor, its cost must not be entirely debited to advancing the phase. Only so much of the cost should be debited to phase-advancing as is represented by the alteration in the motor to make it suitable for this purpose. It must be wound so as to give the larger electromotive force, and its current capacity must be greater than that corresponding to its mechanical power.

Phase-advancing by an idle running motor may or may not be a commercial proposition; phase-advancing by a loaded motor certainly is, especially for the power company, since their share of the cost can only amount to a part of what it would be if they had to do the phase-advancing by an idle-running motor on their own account, instead of getting a customer to help them. At the same time they get the full benefit of a smaller phase angle over the whole system, which enables them to sell more power without having to lay down additional plant. More power without additional capital outlay means a decrease in the fixed charges per unit and consequently a reduction in generating and distributing costs.

* "Journal of the Institution of Electrical Engineers." Vol. 50, p. 329, 1913.

The over-excited synchronous motor has certain virtues, but also one drawback. Amongst the virtues must be mentioned constancy of speed and a high overload capacity, which distinguish it favourably from the ordinary induction motor; but it is also distinguished unfavourably from the induction motor by the difficulty of starting, or rather by the necessity of starting appliances being provided, including a synchroniser.

Some types of synchronous motors have been developed which do not require synchronising and in which the starting appliance is fairly simple. Of these types two may be mentioned: one has been perfected by the Lancashire Dynamo and Motor Company, and the other by the late Mr. Danielsen, of Vesterås, Sweden.

The Lancashire Dynamo and Motor Company's arrangement is shown in Fig. 1. The outer circle represents a 3-phase stator and the inner circle a wound rotor. This rotor may be excited from a small dynamo *e*, and then it becomes the continuous-current field magnet of a synchronous motor, the stator being the armature. At starting, however, the rotor is not excited, but its winding is closed over the resistance shown, and then the rotor winding acts as the secondary circuit of an induction motor. The machine is started in the usual way by gradually reducing the resistance until the contact *a* has advanced to *b* and the whole of the starting resistance is short-circuited. The machine then works like an ordinary induction motor. If now the resistance is again inserted and at the same time the exciting circuit of *e* is closed, the rotor becomes a continuous-current magnet and jumps into step. By the time the contact *a* has been completely withdrawn from the starting resistance the rotor is over-excited, and the machine, whilst giving power mechanically, acts as a phase advancer.

In the Danielsen arrangement (Fig. 2) the three lines, *a*, *b*, *c*, represent the phases of the rotor of an induction motor. Phase *a* is shown by a thicker line to indicate that it has twice the copper section of the other two phases. S is the starter, and the contacts corresponding to the phases *b* and *c* are permanently connected. The contact corresponding to *a* is connected to the joined contacts over a small continuous-current series exciting dynamo *e*, mounted on the motor shaft. During the starting period the connections to the dynamo are short-circuited and the brushes are placed on the axis of the field so that the machine cannot excite.

The motor is started as an induction motor in the usual way, and when up to speed, *i.e.*, when the whole of the starting resistance is short-circuited, the exciting dynamo is inserted by opening the switch above mentioned. It will then be traversed by the rotor current, which has the very low frequency of the slip. Hence the self-induction of the exciter does not interfere with the working of the machine as an induction motor.

If now the brushes are shifted into their working position the machine begins to excite not only itself but also the rotor of the motor, transforming it into a continuous-current magnet. The current enters at phase *a* and passes out by the other two phases in parallel. This is the reason why the copper section of phase *a* is twice that of the other phases. The machine jumps into step and becomes a synchronous motor. The excitation is adjusted by shifting the brushes on the exciter.

It is interesting to enquire what extra amount of material is necessary to make a synchronous motor capable of performing the double duty of motor and phase advancer. The amount of material and in some sense also the cost of the motor may be expressed on the basis of the product of electromotive force and current. The electromotive force is that to which the machine must be excited if it is to act as a phase advancer; and this electromotive force is also that which it would give on open circuit if power were supplied to drive the machine as a generator.

It has been assumed above that this electromotive force exceeds the line voltage E by about 30 per cent. If the machine is running as a phase advancer pure and simple, *i.e.*, is doing no mechanical work, the resultant electromotive force which drives the current through the armature will be 0·3 E. The resistance of the armature is so small compared with the reactance ω L that we may neglect it, and we thus

obtain the following expression for the current (which in this case leads the line electromotive force by 90°)—

$$I = \frac{0 \cdot 3\ E}{\omega L}.$$

The armature winding must be of sufficient section to let this current pass without the permissible temperature rise being exceeded, and the field must be strong enough to make the induced electromotive force = 1·3 E. The rating of the machine will therefore be 1·3 E I.

Now let us enquire what would be the rating of a machine working merely as a motor at unity power factor and taking the same current I. It would have to be excited to 1·045 E, and its rating would therefore be 1·045 E I.

A machine intended to act purely as a phase advancer is therefore 24·5 per cent. larger than a machine intended to act purely as a motor and taking the same current.

How does the case stand if the machine is to act both as a phase advancer and as a motor? It will then have to take a watt component I from the line and to return a leading and wattless component I to the line. The total current passing through the armature will therefore be $I\sqrt{2}$, and the armature voltage on open circuit must be 1·33 E, so that the rating becomes 1·87 E I, or 79 per cent. higher than the rating of the simple motor. Since both components of the current are of the same magnitude the power factor of the over-excited motor is 0·7, the current leading.

The overload capacity of the combined motor and phase advancer is considerable. It will fall out of step at about four times normal load, but the current would then be lagging by 45°. With the machine overloaded to a little under three times its normal load the phase angle would be zero, so that up to this limit the machine still acts as a phase advancer; it should be remembered that a motor taking current at unity power factor added to a group of motors taking current at 0·7 power factor raises the power factor of the whole system.

Fig. 3 shows the vector diagram of the combined motor and phase advancer. O A is the line voltage, A B the voltage to which the machine is excited, and O B is the resultant voltage which produces the current O C. In taking O C as a measure of the current we make the assumption that the ampere scale is ω L times the volt scale. Then O B may also be taken as the current vector rotated through 90°, and its projection on the vertical axis O L becomes a measure of the leading component of the current, its projection O P on the horizontal axis being also a measure of the power component. By a suitable change of scale the latter projection can also be made a measure of the mechanical power.

The circle drawn with A as centre and with a radius representing the voltage to which the motor is excited gives, therefore, the relation between the mechanical power and the magnitude of the leading current injected. It will be seen that up to normal load the leading component does not alter much; and herein lies the advantage of using the phase advancer as a motor. With an overload the decrease in the leading component is more marked, and this component becomes zero at about 2·9 times normal load.

If we now apply this motor phase advancer to the case previously considered, of a group of customers taking 100 kw. at the time of peak load with a power factor of 0·7, and enquire what it will cost to add another 25 kw. of saleable power without increasing the generating plant or line, we find that the added synchronous motor will have a rating of 60 k.v.a. and will take 25 kw. without increasing the line current. The improved power factor will be 0·9.

The cost of the motor is £120, of which £70 must be debited to it in respect of its being a motor and £50 in respect of its being a phase advancer. If this cost were borne by the power company it would mean that by the expenditure of £50 it purchases a market for an additional 25 kw. of saleable power. This is at the rate of £2 per kilowatt. If, on the other hand, the customer is to pay the £2 per kilowatt he will expect a recompense in the shape of a lower tariff or a discount on the general tariff. This discount need not be large. The yearly bill per kilowatt of peak load will naturally vary between wide limits according to the load factor and the price for current; it may be anything between £4 and £10, but taking even the lower figure, a discount of 5 per cent. will provide 10 per cent. for interest and sinking fund on the customer's outlay.

Phase-advancing by a loaded synchronous motor thus becomes a commercial proposition. It should be remembered that the power company has in supplying the additional power no other expense than that incurred for fuel and water, and it could therefore well afford to give a greater discount than 5 per cent.; but as that is about the lowest figure which will tempt the customer to incur the additional expense and the somewhat more complicated operation of the motor as regards starting, and as a suggestion is made later in this paper for a method of metering which works out to about the same discount, this discount of 5 per cent. may be retained as fair to the customer and very favourable to the company.

Phase-advancing Apparatus Applied to Induction Motors.—We have so far only considered the case that a leading current is directly injected into the line; but it is possible to obtain phase advancement by injecting a leading electromotive force into the secondary of an induction motor. This must necessarily react on the primary and thus reduce the original lag in it; and if carried beyond the requirements of the individual motor it may even produce a leading component of the current taken by the motor and so improve the power factor of the system as a whole.

Prof. Miles Walker has read two papers* descriptive of phase advancers designed by him for this purpose, and I have published a general theory of the subject in the "Electrician."† It will therefore not be necessary to enter either into the description or the theory of such apparatus; but as this paper is mainly concerned with the commercial aspect of phase-advancing it will be useful to draw from the general

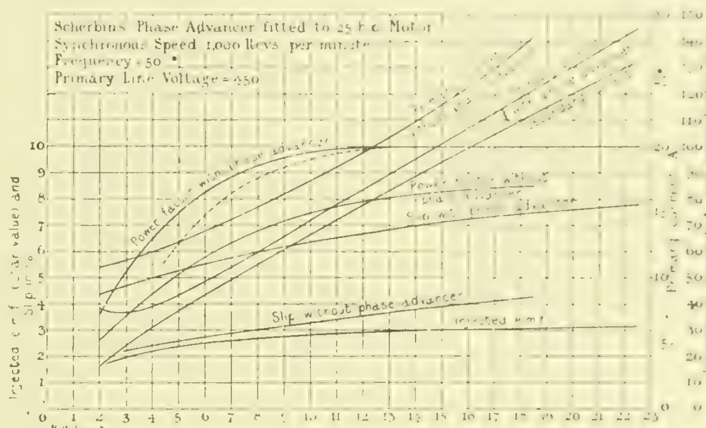


FIG. 5.

theory of phase advancers those conclusions which affect more directly the cost and efficiency.

Let the half-circle in Fig. 4 be the locus of the upper end of the primary current vector, and assume for the sake of simplicity that the stator and rotor have the same winding. Then E D is proportional to the secondary current, and E M is proportional to the slip-ring voltage with the secondary open. The voltage lost in the rotor, the so-called slip voltage, may be measured off from E along E M, but for clearness to a larger scale. Let this be E R_0 = I R_2, where I = E D, and R_2 is the resistance of one rotor phase. The torque given by the motor is proportional to the height of D above the horizontal axis, and since the slip is small, this may also be taken as approximately representing the power. All this refers to the motor working alone.

If now a phase advancer be added and if its action is such as to make the power factor unity, then the point D must for the same load move to A, thereby reducing the primary current, but increasing the secondary current, so that the ohmic rotor loss is increased by R_0 R.

The phase advancer has a resistance ρ, and to overcome this an ohmic loss ρ I = R_0 S is incurred. The slip voltage must therefore have a power component E S. It must also have a wattless component, namely, that represented by the difference of the electromotive force introduced minus the electromotive force of self-induction lost in the phase advancer itself. Let S L represent the latter and L B the former, then the wattless component of the slip voltage is S B. This combined with E S gives the total slip voltage E B, which is

* "Journal of the Institution of Electrical Engineers," Vol XLII., p. [illegible], 1909, and Vol. L., p. 329. 1913.

† "Electrician," Vol. LXIX., pp 222 and 272, 1912.

obviously greater than E R_0. This means that by using a phase advancer the natural slip is increased.

The rating of the phase advancer as a generator, and therefore its cost, is obviously proportional to its volt-ampere capacity, *i.e.*, to the product of E A and L B. E A is given by the load, and is therefore fixed, but L B is to a certain extent in the hands of the designer. If he designs his motor for a small natural slip and uses a phase advancer having small ohmic and inductive losses, then L B will be small, and the cost of the phase advancer will also be small. If the natural slip of the motor is large, then the phase advancer becomes more expensive.

It should be noted that for the sake of clearness it was necessary to exaggerate the length of the lines R_0 R, R S, and S L. In reality the ohmic loss in the phase advancer need not be more than one-tenth that in the rotor, whilst the

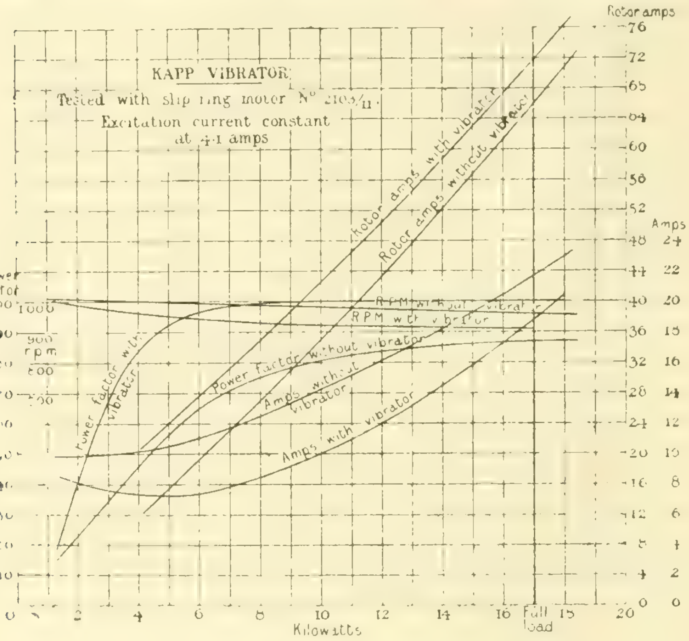


FIG. 6.

inductive drop is also very small, and in some cases negligible for the same reason that the inductive drop in the rotor itself may generally be neglected. We may then consider E S to represent the natural slip voltage augmented by 10-20 per cent., and S B the injected electromotive force.

From these relations it follows that a small natural slip is of far greater importance than a large natural power factor. With an increased power factor the point O would move slightly nearer to E, and the primary current would lead slightly. If, on the other hand, the natural slip could be halved, the triangle E S B would shrink to half its size, so that the electromotive force introduced need only be half the former value, and the k.v.a. output which must be given by the phase advancer would be halved.

If, then, an engineer is called upon to design a motor to work with a phase advancer, he should aim at a small natural slip, even at the cost of a somewhat reduced natural power factor; he will thereby get a cheaper motor and also a cheaper phase advancer, so that the cost of the set capable of giving unity power factor need not be greater than the cost of a motor designed to work alone. But in the latter case the power factor cannot be much over 0·9; so that the unity power factor is practically obtained without extra expenditure.

This theoretical conclusion is borne out in practice. In my laboratory at the Birmingham University is a Brown-Boveri induction motor of 25 h.p. fitted with a Scherbius phase advancer. At full load the set has unity power factor, and its efficiency is 88 per cent. The synchronous speed is 1,000 revs. per minute, and the weight is 800lbs. The figures, 1,000 revs., 25 h.p., and 800lbs., agree fairly well with good English practice for induction motors having at full load a power factor of 0·9, so that in the case here cited the improvement of power factor is indeed obtained without any increase in material.

In Fig. 4 the semi-circle is the locus of the primary current of the motor working alone, and the larger circle is the locus of the primary current if the phase advancer is added. This statement, however, carries with it the assumption that the magnetic flux in the phase advancer is strictly proportional to the rotor current; in other words, that the part which in the phase advancer performs the function of a field magnet is worked well below saturation. If, however, saturation sets in at higher loads, then there is no longer simple proportionality between the injected electromotive force and the rotor current, so that at heavy load the line E B becomes less inclined, and the centre C of the larger circle lies lower. This is rather an advantage than otherwise, because it enables the designer to compensate at, say, two-thirds load without over-compensating at full load. In the Scherbius set above mentioned, the designer has made use of this saturation effect in order to raise the power-factor curve at a reduced load above what it would have been if for a power factor of unity at full load there had been strict proportionality between the rotor current and injected electromotive force.

Fig. 5 gives the results of a test. The dotted power-factor curve is calculated on the supposition that there is no saturation. The diagram also gives the tests results as regards the primary and secondary currents, injected voltage, and slip.

A test was made with the same motor and the phase advancer out of circuit. The results, as regards power factor, primary current, and slip, are given by way of comparison in the same diagram. Since the load of the motor is limited by heating, and this depends mainly on the primary current, it is obvious that the motor when deprived of its phase advancer cannot give the same power as with a phase advancer. Hence the curves are not carried as far as with the phase advancer in action. I am indebted to Mr. G. A. Shearing, M.Sc., for his assistance in making the tests and plotting the curves.

The distinguishing feature of the Scherbius phase advancer is the absence of a stator. The machine merely consists of an armature and commutator; but the winding, instead of lying on the circumference of the drum, is embedded in a circle of holes well within the external diameter of the armature plates, so that the iron outside the holes is available as an external path for the flux which passes through the winding. This flux is produced by the combined action of the three rotor currents. It revolves in space with the frequency corresponding to the slip.

Let the total number of active wires be z, then $z/3$ wires are allotted to each of the three phases.

If—

Φ = flux in megalines,

$2p$ = number of poles for which the armature is wound,

f = slip frequency,

and—

n = number of revolutions per second at which the armature is driven;

then the electromotive force injected (star value) is given for a wave-wound armature by—

$$e = \frac{1}{p}\, 0\cdot7\, \Phi\, \frac{z}{100}\left(n - \frac{f}{p}\right).$$

The term in brackets represents the relative speed between the slowly revolving flux and the quickly revolving armature. If the armature were driven at a speed no greater than that corresponding to the slip frequency, the electromotive force would be zero; and if the armature were standing still, the electromotive force would be negative, namely, that due to self-induction. This is the value corresponding to the length of S L in Fig. 4.

In the Scherbius phase advancer mentioned above, the armature has a 4-pole wave winding, and the speed n is fixed by the slip, since the phase advancer is fixed to the shaft of the motor. By introducing the slip σ, and synchronous speed n_s, the above formula may be written in the more convenient form—

$$e = 0\cdot35\, \Phi\, \frac{z}{100}\, n_s\, (1 - 2\cdot5\,\sigma).$$

It will be seen that the term in brackets increases slightly as the slip is decreased by reason of the load being reduced. This means that the ratio of the injected electromotive force to the flux is a little greater at light load than at full load; and this circumstance, together with the effect of saturation already mentioned, is responsible for the difference between

the actual power-factor curve shown by the full line in Fig. 5 and the dotted curve which has been determined on the supposition that there is no saturation, and that e is strictly proportional to I.

When applied to large motors the phase advancer is not mounted on the motor shaft, but is a separate machine placed by the side of the motor, and driven from it either by belt or preferably by a small 3-phase motor. The power necessary to drive the phase advancer is only that required to supply the

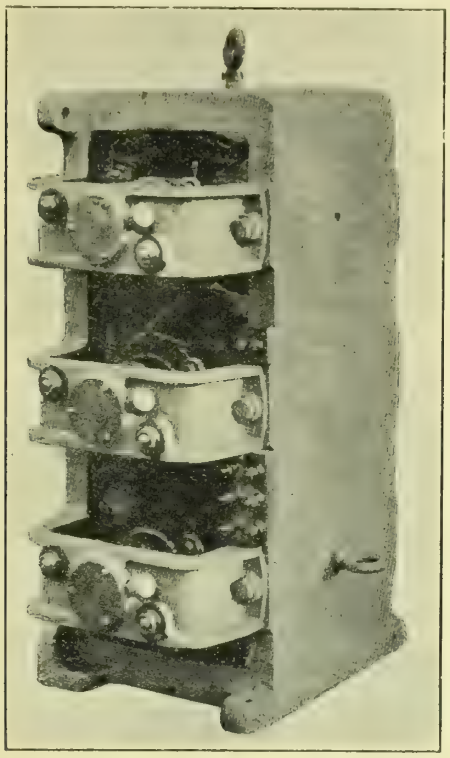


FIG. 7.

friction, windage, and iron losses, but not the copper losses, since these are provided by the rotor.

The phase advancer here described, as well that which Prof. Miles Walker has recently brought to the notice of this Institution, belong to what may be called the rotational type, because the leading electromotive force is produced by the rotation of an armature in a magnetic field. There is, however, another principle which can be applied to phase advancement, viz., the free oscillation of an armature in a continuous current field. To distinguish such a machine from the rotational type I call it a vibrator.

M. Leblanc was the first engineer to call attention to both the rotational and the vibrating principles of phase advancement, and he has patented an apparatus under the name "recuperator," in which the vibrating principle was used to produce phase advancement. The "recuperator" consists of a copper disc swinging within an annular unipolar field. The current flows through the disc radially between a rubbing contact at the centre and a mercury-trough contact at the circumference. For this purpose the rim of the disc is bent down so as to dip all round into the mercury. To keep the field from oscillating, a second and fixed disc is placed parallel to the oscillating disc within the polar cavity, and so connected that the current flows through the two discs in opposite directions.

To avoid the drawback of a mercury contact M. Leblanc has suggested as an alternative design the use of a Derozier disc armature; but in every case he has laid stress on the necessity of keeping the swinging conductor as light as possible, and that therefore only the conductor and not an iron core should participate in the motion.

The author does not know whether the recuperator has found practical application, but he thinks it unlikely, because the disc form, although light, has far too great a moment of inertia, especially, if to avoid mercury contacts, it is adopted in the shape of a Derozier armature, because then the end connections on the outer circumference add materially to the moment of inertia without contributing anything to the dynamic effect.

When the author designed his vibrator he was not aware of M. Leblanc's recuperator, but he willingly acknowledged M. Leblanc's priority in having been the first to draw attention to the fact that phase advancement may be produced by making use of the physical principle that a leading electromotive force is generated in an alternating-current conductor allowed to swing freely in a continuous-current field.

Any continuous-current armature if traversed by an alternating current of low frequency will tend to vibrate, but with a machine of the usual proportions this tendency is too weak to be practically utilised. In order to get a serviceable phase advancer the armature must be bipolar, of small diameter and great length, the air gap must be as small as mechanically possible, and the saturation of teeth and core must be very high, not only because a strong field is desirable, but also to avoid unbalanced magnetic attraction, which with a small air-gap would be unavoidable if the teeth were only moderately saturated. The leading electromotive force injected by the vibrator is given by the formula—

$$e_v = \frac{0 \cdot 1}{m} \left(\frac{\phi}{\tau} \right)^2 \frac{\mathrm{I}}{\omega}.$$

where m = the mass of the armature in units of 9·81 kg reduced to its circumference,

ϕ = the continuous-current field in megalines,

τ = distance from wire to wire on the armature,

$\omega = 2 \pi f$, the angular speed corresponding to the slip frequency f,

and I the current in amperes.

This formula may with sufficient approximation be also written thus—

$$e_v = 0 \cdot 1 \frac{(\phi z)^2 \ \mathrm{I}}{\mathrm{G\,D}^2 \ \omega},$$

where z = the number of active conductors,

and $\mathrm{G\,D}^2$ = the flywheel effect of the armature in kilogram-cm.^{2}.

The output of each vibrator armature in volt-amperes is e_vI, and this is given by—

$$\mathrm{V\,A} = \frac{3 \cdot 8}{\mathrm{G}\omega} (\phi \triangle)^2,$$

where $\triangle$ is the current density in effective amperes per centimetre of armature circumference.

It will be seen that the magnitude of the injected electromotive force is proportional to the ratio of current and slip frequency. Since this ratio decreases only slightly as the load decreases, the injected electromotive force does not fall off proportionally with the load, but at a much lower rate, with the result that the effect of the phase advancer is relatively greater at low loads, and this is just what is wanted.

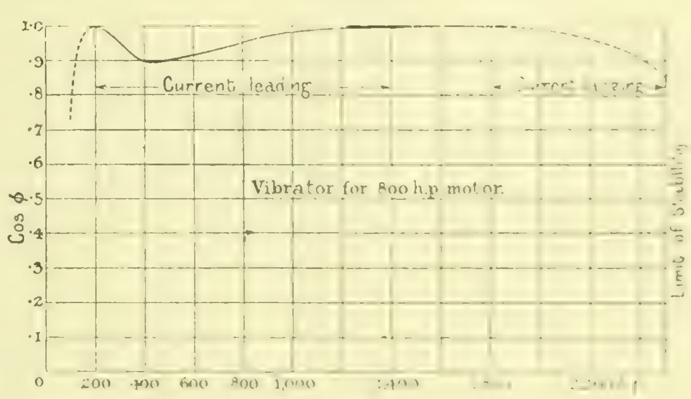


FIG. 8.

It is especially at low loads where there is greatest need for improving the power factor. This effect will be seen in Fig. 6, which represents test results obtained with a vibrator made by the Sandycroft Foundry Company. (I am indebted to Mr. Hunt for these curves.) At one-quarter load the power factor is already 0·87, and at half-load it is unity, maintaining this value up to full load and beyond.

We have here the same effect as can be obtained in the rotary phase advancer by saturation, only in the case of the vibrator this effect is still more pronounced. Fig. 6 gives also the primary and secondary currents and the speed, both with and without the vibrator. It will be noticed that the effect

of the vibrator is to decrease the primary current considerably and to increase the secondary current slightly; this means on the whole a smaller copper loss in the motor.

A photograph of this phase advancer is reproduced in Fig. 7. The three pairs of field cores and the common yoke frame are in one casting without any joints. The only machining required is the boring of the polar cavities and the facing up of the surfaces to which the bearing brackets are bolted. The armature shafts are carried in ball bearings. The resistance of each armature hot is 0·048 ohm, and when the three armatures are mesh-coupled they can deal with a slip-ring current up to 120 amperes. The current in each armature is then 70 amperes, and the ohmic loss in the winding 3·35 volts, to which must be added the loss by contact resistance of the brushes. This is small, since it is possible to use copper-carbon brushes. There is no sparking. When the current has crest value the armature is at rest, and when the armature has maximum speed and the frequency of commutation has maximum value the current is zero. At intermediate points there is some reactance voltage of commutation, but this is extremely small—only a fraction of a volt. The armature is 4½in. diam. and its core 8¼in. long. The vibrator was tested with a 60 h.p. Hunt cascade motor having six pairs of tappings. As the vibrator has only three armatures it could only deal with half the secondary circuit of the motor. The improvement in power factor was nevertheless very marked. The power factor was raised at half-load from 0·72 to 0·91, and at full load from 0·81 to 0·93.

The author is not able to give results from actual practice with a vibrator fitted to a large motor, because the small vibrator made by the Sandycroft Foundry Company for the 60 h.p. Hunt cascade motor is as yet the only representative of this type of machine in this country. A continental firm is making one for a 450 h.p. motor, but it has not yet been finished. The author has, however, made a design for a vibrator to be applied to the 800 h.p. motor of which particulars were given in Prof. Miles Walker's paper,* and he finds that each of the three armatures would be 13 cm. diam. and the length of core 33 cm. The armature resistance would be 7·2/1,000 ohms, and a flux $\phi = 3·45$ megalines would be obtained with a magnetomotive force of 6,700 ampere-turns. At full load the injected electromotive force is 23 volts. The excitation requires an expenditure of 700 watts, and the losses in the copper and iron, in brush friction, and in contact resistance, come to 1,300 watts, making a total expenditure of 2 kw. for the vibrator, against which must be set the reduction of losses in the motor due to the better power factor.

Fig. 8 gives the predetermined power-factor curve. The power factor of the 800 h.p. motor would with this vibrator be brought to unity at one-quarter load; at half-load it would be 0·9 with a leading current; at full load it would be 0·95 with a leading current; and at twice full load it would again be unity. Above this output the current lags with a power factor of 0·92 at treble load, when the limit of stability is approached. The weight of the vibrator is, as near as can be estimated, 18 cwt., and the floor space occupied is 18in. by 3ft., the vibrator standing 3ft. high.

Whether a rotary or a vibrating machine be used as a phase advancer, the power to drive it is in either case very small, and will generally be more than covered by the reduced losses in the motor. The efficiency of any given motor, whether it works with or without a phase advancer, will therefore not be appreciably altered. There may, however, be a gain in the yearly energy efficiency, as the use of a phase advancer enables one to do with a smaller motor, since the overload capacity is increased. A smaller motor has smaller losses, and consequently the customer of a power company using his motors with a phase advancer attached will effect a certain saving in his bill for current even if the power company does not grant a special discount for his taking current at a high power factor.

Now how does the case stand with the power company? The cost for electrical energy generated and transmitted is made up of several parts, of which, however, only two need be considered. One is the actual cost of generation, including a certain percentage of loss in transmission, and the other is independent of the amount of energy generated, but depends only on the cost of the plant which must be installed to provide the service. Part of the plant, such as the prime movers, is only very slightly affected by the power factor; but the electrical plant, including the line and step-down transformers at the customer's end, is materially affected by it. The cost of the electrical plant is determined not by the true power, but by the output defined in volt-amperes; consequently it is only fair that a customer who takes his power adulterated by a large proportion of sin ϕ should in his payment for current recompense the company for the extra plant capacity necessary for the generation and transmission of wattless current. The customer should therefore not only pay for the true kilowatt-hours he takes, but also something for the k.v.a.-hours.

* "Journal of the Institution of Electrical Engineers," Vol. L., p. 329. 1913.

This reasoning is the basis of a system of metering invented by Prof. R. Arno, of Milan. He and Signor Conti, the engineer to several Italian power companies, investigated the cost of generation and transmission as affected by power factor, and they found that the cost may, with sufficient accuracy for practical work, be taken as proportional to the sum of two-thirds of the watt-hours plus one-third of the volt-ampere-hours. Having settled this as a basis for charging, Prof. Arno set to work to design a meter which will register according to this formula; and he has also indicated a way in which any meter may be adapted to register two-thirds of the watt-hours and one-third of the volt-ampere-hours.

In meters of the electrodynamic type where the moving system is a little armature traversed by a current in phase with the electromotive force and the field is produced by the main current, a small lag is given to the armature current. In meters of the induction type where the moving system is a disc revolving under the combined influence of a shunt and main field, a small lag beyond 90° is given to the shunt field. The angle of lag in either case is so chosen that at the predominant power factor the meter registers according to Prof. Arno's formula. Thus for installations mainly supplying light the lag of the shunt current behind the electromotive force is 5° in dynamometric meters and 95° in induction meters. The meter will then register with a negligible error at any power factor between 1 and 0·85. For installations consisting mainly of motors the lag is 14° for electrodynamic and 104° for induction meters. The extra lag of 14° may be produced by a slight alteration in the compensating coil of the shunt field.

Prof. Arno states that meters so adjusted may be used in cases where the power factor varies from 0·5 to 0·9. For large consumers where great accuracy in the metering is essential, two meters side by side may be installed, one registering kilowatt-hours and the other k.v.a.-hours. The charge to be made to the consumer can then be calculated on the two-thirds and one-third basis, or on any other basis which may more nearly fit the special conditions of the power company's plant.

It is of interest to enquire what saving a customer may effect in his current bill if he uses a phase advancer. Take a large customer using large and small motors with an aggregate power of 1,000 kw. and a power factor of 0·75. Since only the large motors can be fitted with phase advancers, it will scarcely be possible to raise the power factor to unity, but a value of 0·95 may be obtained if large motors aggregating 700 kw. to 800 kw. are so fitted. With a load factor of 34 to 35 per cent. the yearly consumption will be 3 million kilowatt-hours. With 0·75 power factor the Arno meter would register 3⅓ million units; but after fitting phase advancers the meter would register only 3·053 million units. With current at 0·5d. per unit this makes a difference of about £600 in the bill for current.

This, or something approaching this figure, represents the saving to the power company owing to their having to supply very little wattless current. If, then, this saving is divided between the company and the consumer the latter gets £300 as a return for his capital outlay on phase advancers. To provide such apparatus for motors aggregating 800 kw. would cost between £300 and £400, so that the phase advancers would prove an excellent investment for the customer, and be still more profitable to the company. The latter not only reduce their working expenses by £300 a year, but they also may increase their sale of current by taking on more consumers to the extent to which their plant has been liberated from wattless current.

INDUSTRIAL AND TRADE NOTES.

The Factory Act and Gauge glass Protectors.—A fine of £5 and costs was recently imposed on the Palmer Shipbuilding and Iron Company, at Jarrow, for a breach of the Factory Act, by not having had protection guards on the gauge glasses of their crane locomotives. Mr. W. Lauder, H.M. Inspector of Factories, said that on two previous occasions the company had been convicted.

Light Railways.—The Board of Trade have recently confirmed the under mentioned Order made by the Light Railway Commissioners: Harrington and Lowca Light Railway Order, 1913, authorising the acquisition, reconstruction, and working for passenger traffic, as a light railway under the Light Railways Act, 1896, of an existing mineral railway from the Harrington Collieries at Lowca to Harrington, in the county of Cumberland.

The Amalgamated Society of Engineers and "Down-tools" Policy.—The provisional executive of the Amalgamated Society of Engineers has issued a warning to its 150,000 members stating that in some instances the members have adopted a down tools policy. In each instance it has not been a success, but rather a failure. Such a policy, says the executive, handicaps the officials, and, further, is clearly against the rules. Therefore in future any members who strike without permission will not be paid any benefits.

Bridge-building Feat.—A smart feat of engineering work was accomplished on the Waverley route on the 11th inst. by the erection of a new girder bridge across the railway lines at Eskbank Station. The work was commenced just after midnight on the Saturday, large squads of men being engaged. The bridge was brought from the Easter Road works and swung in position by a large steam crane. The work was rapidly executed, and the morning train from St. Pancras and Carlisle got a clear passage.

Employment in the Engineering Trades.—According to the report for April issued by the labour department of the Board of Trade, unemployment is still decreasing and wages are still rising. Compared with a year ago, when employment had not fully recovered from the effects of the great coal dispute, all the principal industries except tinplate showed an improvement. In figures, trade unions, with a membership of close upon a million, reported only 1·7 per cent. of their members as unemployed, compared with 3·6 per cent. at the end of April last year.

Accidents on Railways during 1912.—Returns of accidents and casualties on the railways of the United Kingdom during 1912, just issued by the Board of Trade, show that the total number of persons killed was 1,011, while the injured numbered 8,700, these figures being respectively a decrease of 59 and an increase of 355 on those for the previous year. Accidents to trains, rolling-stock, permanent way, &c., accounted for the deaths of 20 passengers and six employes, and injuries to 683 passengers and 154 employés. Other accidents were responsible for the deaths of 90 passengers and 337 employés, and injuries to 2,145 passengers and 5,408 employés.

Boilermakers' Strike Vote.—The report of the Boilermakers' Society just issued states that the result of the ballot on the question of giving notice to cease work unless a special advance of 2½ per cent. is given on piecework riveting rates is as follows: For a month's notice, 1,027; against, 1,550. In view of the decision to act with the other shipbuilding trades in pressing for a general advance, the Executive Council of the Boilermakers' Society have decided to approach the employers for a further conference in respect of the special advance of 2½ per cent. With regard to the claim for a general advance of 5 per cent., the members are asked to vote not later than May 30th on the following proposal: "That it be left in the hands of the Executive Council to meet representatives of the other shipbuilding trades and fix a date when all trade unionists in the federated shipyards will take action to obtain the advance asked for." At the present moment there seems every likelihood of a vote in favour of this proposal, which empowers the executive to fix a date along with the other trades to cease work to obtain the advance if necessary.

The Manufacture of Oxygen.—On Saturday last a party of members of the Newcastle and District Association of Foremen Engineers and Draughtsmen visited, by invitation, the Heaton works of the British Oxygen Company, Ltd. Mr. C. W. James, manager of the works, said that in 1886 oxygen was sold at 1s. a foot, but the processes for making it were improved until they reached the liquid air method, which made better and cheaper oxygen. He thought the British Oxygen Company had done something in lowering the price of oxygen from 1s. per foot to something less than a half-penny. Mr. James gave a few simple but interesting experiments of the properties of oxygen, the manufacture of which at the company's works was by means of liquid air. The air was drawn through purifiers, after which it passed through the air compressors, and in three stages heat was extracted by cooling the air in water. Oxygen was separated from the other constituents of the liquid air and afterwards sent into the gas holders, the oxygen being afterwards drawn and filled into cylinders at a pressure of about 1,800lbs. to the square inch. The cylinders were subjected to a hydraulic test, and were made strong enough to stand a pressure of 3,300lbs. Each cylinder was numbered and tested every year. The life of a cylinder was 15 or 20 years, or perhaps rather more now that they were made of thicker metal. Mr. James explained the extreme range of temperature at which the company worked and said that range was something like 7,500°. In the past four years the company had improved the apparatus for cutting and welding, and he showed a portable contrivance which, by a combination of petrol and oxygen, was capable of making a clean cut in steel an inch thick. The visitors afterwards viewed some very interesting demonstrations in cutting and welding. Mr. James was cordially thanked for the opportunity he had afforded the members of the Association to see over the works.

Annual Report of the Boilermakers' Society.—The 78th annual report of the United Society of Boilermakers and Iron and Steel Shipbuilders has just been issued. The general secretary (Mr. John Hill), in a prefatory address, states that the year 1912 was a good one for the union. There had been an unprecedented boom in trade, serious disputes had been averted, and wages had been considerably advanced in all districts. During the 12 months they had been successful, through the Engineering and Shipbuilding Trades Federation, in abolishing the discharge note without which no man had been employed in federated shipyards. On the question of a national shipyard agreement the members of the society had voted in various moods during the year. A national conference of the members held in September recommended an agreement between the employers and themselves. The vote was taken in November and was favourable. Meetings with the employers had been held on the question, but without any result as yet. Another national agreement considered during the year was the demarcation agreement, which had now been accepted by all the engineering and shipbuilding trades and the two big federations of engineering and shipbuilding employers. The society had negotiated this question for nearly three years in company with some 30 other trades. The question of amalgamation was still very much a matter of talk. During the year the society made overtures to the Associated Shipwrights and the Amalgamated Society of Engineers. The shipwrights asked the boilermakers to suspend negotiations with the A.S.E. while they were negotiating with the shipwrights. This the boilermakers agreed to. The shipwrights had made stipulations which had delayed negotiations, and there the matter rested. The total membership of the society at the end of 1912 was 61,835, an increase of 6,525 compared with 1911. The income of the society from members' contributions, entrances, propositions, and levies amounted to £185,201. 4s. 8d., and the gross income for the year was £371,873. 2s. 4d. The total expenditure was £144,728 10s. 7d., leaving a balance at the close of the year of £227,144 11s. 8d., or a sum equivalent to £3. 13s. 5d. per head of membership.

Wailes, Dove, & Co.'s Exhibit at the Liverpool Exhibition.—Messrs. Wailes, Dove, & Co., Ltd., Newcastle on Tyne, the patentees and sole manufacturers of the well known patent "Bitumastic" enamels, coverings, and solution, for the prevention of corrosion in iron and steel and the protection and preservation of wood, concrete roofs, walls, &c., have an attractive display on Stand No. 271 at the Liverpool Exhibition, which was opened yesterday. On the stand is shown a model of the midship section of a vessel, and also a model workshop with smokestacks, &c. These are all coated with their different "Bitumastic" specialities. There is also shown a small model of ships' steel deck plating, flushed up and levelled with patent "Bitumastic" deck covering, on which "Corticene" is laid. This material is similar to that applied successfully to the promenade, shelter, upper, main, and lower decks of the Cunard liner "Mauretania" and other liners. The advantages obtained by using this material in lieu of wood decks are: No piercing of decks, more head room in 'tween decks, steelwork efficiently protected, "Corticene," rubber tiling or parquetry easily laid on, cheaper and more durable than wood and less weight, perfect sanitation, more air space, no accumulation of foreign matter as is usual under wood decks. Conclusive proof of the effectiveness of "Bitumastic" enamel is seen by the condition of iron bolts after submersion in a chemical solution. The parts not coated with "Bitumastic" enamel are badly corroded by the acid, but the remaining portions show no signs of deterioration, the enamel being absolutely unaffected. "Bitumastic" enamel was also selected for protecting the huge lock gates (46 pairs, area over 3,000,000 sq. ft.) on the Panama Canal after endurance tests against over 300 competitors. Other notable contracts include the coating of the Cunard liners "Aquitania," "Mauretania," "Lusitania," the "Olympic" (White Star), "Alsatian" and "Calgarian" (Allan Line), "Imperator" (Hamburg American Line), &c., in addition to a number of battle ships, cruisers, submarines, &c., for the British and foreign Admiralties. The firm have also in hand contracts for various kinds of iron and steel structures on land, "Bitumastic" proving invaluable for the protection of bridges, water tanks, pit head gears, smoke stacks, refrigerating plant, corrugated iron buildings and roofs, &c., exposed to acid and alkali fumes, extremes of weather, &c.

NEW PATENTS.

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Apparatus for separating gases and vapours including hydrocarbons. Arnaud. 4808 and 4809.
Cooling internal combustion engines. Adams, De Normanville, and Adams Manufacturing Company. 7344.
Starting internal combustion engines. Cocks. 7449.
Internal combustion engines. Hall. 7793.
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Change-speed gear. Perrot & Matthew. 9796.
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Turbines. Josse & Christlein. 9975.
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Detachably securing the heads or nuts of bolts. Holt. 10127.
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Method of hardening iron and steel. Boyd. 15966.
Governing mechanism for internal-combustion engines. British Thomson-Houston Company. 16412.
Vaporisers of internal combustion engines. Crossley & Webb. 16748.
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Balancing of rotating masses. Soc. Anon. pour L'Exploitation des Procédés Westinghouse Leblanc. 16809.
Signalling on railways. Blackall & Jacobs. 17035.
Lubricating devices. Didier. 18280.
Coal cutting machines. Mavor & Coulson, Ltd., and Moore. 18870.
Rock drills. Gilman. 19508.
Internal-combustion engines. Weisz. 19553.
Internal combustion engines using heavy fuels. Pieper. 21176.
Meters of the Venturi type for liquids. Kennedy. 21498.
Internal combustion traction engines. Fowler & Cooper. 21632.
Internal-combustion engines. Rosner. 21751.
Furnaces. Hill. 21923.
Boiler tube cleaner systems. Liddle. 22493.
Speedometers. Veigel. 22824.
Ships' steering gear. Royston. 23121
Furnaces. Hill. 23439.
Lathe tool-holders. Liebstein. 23498.
Foundry moulding machines. Bermond. 25128.
Ball bearing arrangement for displaceably mounted shafts. Deutsche Waffen und Munitionsfabriken. 26185.
Means for adjusting ball bearings. Parkes. 26271.
Rotary blowers and pumps. Shepherd & Hayes. 26526
Fans or air propellers. Shepherd & Hayes. 26527.
Synchronising devices for facilitating the coupling of rotating shafts. Yarrow. 27095.
Connecting rods. Esnault Pelterie. 28485.
Rotary pumps. Siemens Bros. Dynamo Works. 28906.
Double sided chuck. Jones. 30053.

1913.

Dampers for use in connection with steam superheaters. Bolton. 62.
Lubricating pumps. Robert Bosch. 296.
Pistons for revolving cylinder engines. Berliner. 2216.
Former devices for lathes. Liebert & Gartside. 4447.
Rotary pumps. Klinger. 5417.
Operating compound steam turbines. Bergmann Elektricitats Werke Akt.-Ges. 6265.
Hydraulic rams. Blake. 6447.

ELECTRICAL, 1912.

Alternating-current machinery. Akt.-Ges. Brown, Boverie, et Cie. 7258.
Automatic toll recorder for telephone systems. Godfree. 7264.
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Electric incandescence filaments. Hansen & Mohr. 9941.
Electrically heated apparatus. Marks. 10029.
Electric impulse transmitters. Automatic Telephone Manufacturing Company. 10120.
Magneto current generators. Podlesak. 10209.
Telephone systems. Martin. 10376.
Electrodes for primary or secondary batteries. Heil. 10541.
Electric motors. Submersible and J. L. Motors, Ltd., and Cooper. 10654.
Dynamos. Submersible and J.-L. Motors, Ltd., and Poynder. 10655.
Electric heating elements. Electric and Ordnance Accessories Company, and Davies. 10765.
Transmission of electric energy at a distance without connecting wires. Galletti. 10863.
Electric circuit closing devices. Nalder Bros. & Thompson, Ltd., and Harris. 11260.
Electric water-heater. Mann. 11849.
Electric insulators. Meirowsky. 13365.
Wireless telegraphy. Dubilier. 14015.
Electric controllers and starting switches. Siemens Bros. Dynamo Works, Ltd., and Payne. 16343.
Apparatus for transforming direct current into alternating current. Hildebrand. 17346.
Protective devices for electric circuits. British Thomson Houston Company. 17680.
Arc lamp electrodes. British Thomson-Houston Company. 18689.
Controlling devices for electric lamps. Johnson. 22127.
Wireless telegraphy. Goldschmidt. 23734.
Electrical heating units. Marks. 24776.
Ignition devices for internal combustion engines. Podlesak. 25646.

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Receiver for submarine signalling. Signal Ges. 1996.
Telephonic transmitters. Grissinger. 2928.
Protective device for the circuits of electric motors. Glenn and British Pneumatic Railway Signal Company. 3446.
Electric motor controlling devices. British Thomson-Houston Company, and Britton. 4093.
Polyphase current commutator motors. Bergmann Elektricitats Werke Akt. Ges. 4691.

METAL QUOTATIONS.

TUESDAY, MAY 20TH.

Aluminium ingot	95/- per cwt.
" wire, according to sizes, &c. ......from	112/- "
" sheets " " ...... "	126/- "
Antimony ......£31/-/- to	£33/-/- per ton.
Brass, rolled	8½d. per lb.
" tubes (brazed)	10$\frac{1}{8}$d. "
" " (solid drawn)	9d. "
" " wire	8$\frac{7}{8}$d. "
Copper, Standard	£68/12/6 per ton.
Iron, Cleveland	69/6 "
" Scotch	75/6 "
Lead, English	£19/10/- "
" Foreign (soft)	£19/7/6 "
Mica (in original cases), small	6d. to 3/- per lb.
" " " medium	3/6 to 6/- "
" " " large	7/6 to 11/- "
Quicksilver	£7/10/- per bottle.
Silver	28$\frac{1}{16}$d. per oz.
Spelter	£24/15/- per ton.
Tin, block	£218/-/- "
Tin plates	14/3 "
Zinc sheets (Silesian)	£28/10/- "
" (Stettin; Vieille Montagne)	£28/12/6 "

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Edited by
WILLIAM H. FOWLER
Wh. Sc., M.Inst C.E.

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Proposed Manchester International Exhibition.

FOR some time the proposal to hold an international exhibition at Manchester in the near future has been under discussion. When first mooted, however, there was more than a suspicion that the idea was being put forward by professional promoters, and enthusiasm therefore in the commercial section of the community was lacking, for there has been a growing feeling amongst business firms that "exhibitions" such as have been witnessed at various centres in the country during recent years have been much too frequent, and instead of being what they purported to be have been little more than commercial ventures run by advertising contractors, and the manufacturers in several trades have, in order to protect themselves from what they had come to regard as an imposition, banded themselves into associations to regulate the organisation and frequency of such displays. A committee, however, was appointed to enquire into the matter, and the report presented to a city meeting called by the Lord Mayor puts the proposal on a much more satisfactory basis than was suggested in the first instance. For many trades, and especially engineering, Manchester is probably as convenient a centre as any that could be chosen. But to be worthy of the city the exhibition would need to be international in its scope and organised on a public basis, and, as over a quarter of a century has elapsed since an exhibition of this character was held there, another one can hardly be regarded as premature. The magnificence of the display made in 1887, and which "Punch" wittily described as "the gem of the Jubilee," was universally acknowledged. Unlike many exhibitions, it resulted in a handsome profit and the distribution of nearly £50,000 amongst Lancashire charities. At the meeting held on the 22nd inst. the committee reported that several suitable sites were available, free from all liability and restrictions in respect to personal contracts or influence, and a resolution was passed that if a successful exhibition was to be held it would be necessary to have the active co-operation of the Lord Mayor of Manchester, as well as the leading citizens of the surround-

ing towns. This co-operation is certainly indispensable to a successful issue of the proposal, and we have no doubt it could be secured, but any scheme must be absolutely free from taint of the exhibition promoter. We think the committee are somewhat premature in suggesting next year as a date, because an exhibition on a suitable scale would require a good deal of thought and organisation. The following year, 1915, would, in our opinion, be quite early enough to permit of requisite care in the preliminary arrangements, while another reason for that date is it is practically certain the British Association will then hold its annual meeting in Manchester.

The Use of Benzol in Motors.

THE serious appreciation in the price of petrol that has occurred within the last year or two has, as our readers will be aware, suggested the use of other substitutes for that fuel in engines for motor vehicles, and benzol has been put forward as being cheaper and having a higher calorific value. This is so, and to a limited extent the fuel is being used, but there are difficulties in its practical application that may be easily overlooked and which it is desirable to recognise. In the first place, benzol is not so convenient for engine-starting purposes, owing to its tendency to deposit soot if the cylinder is not hot and so clog the rubbing surfaces. For this reason, petrol must be used until the engine is sufficiently hot to prevent this deposition. This change in fuel supply necessitates a readjustment of the air supply and hence of the carburetter. The change may not be difficult with an experienced driver, but the possibility of an engine going wrong at some inopportune moment through slight carelessness or lack of judgment is not a risk that the average motorist cares to face. No doubt it may be possible by mechanical appliances to make the necessary adjustments more or less fool-proof, but such devices can only be arrived at after considerable experience. Another factor, too, that must not be overlooked is that though benzol is considerably cheaper at the moment than petrol, its supply, as compared with petrol, is, comparatively speaking, very limited, while its chemical composition and properties are not, like petrol, reduced to invariable standards, and until this was done it would not be easy to find a solution of the carburetter difficulty; and, finally, it must not be forgotten that the law of supply and demand would apply to benzol as to any other commodity, so that if an extra demand arose, prices would inevitably rise with it and rapidly diminish any economic advantage which might at present exist.

Boiler Explosion on ss. "City of Liverpool."—The formal investigation ordered by the Board of Trade to be held in this matter is fixed for hearing in the Grand Jury Room, St. George's Hall, Liverpool, on Thursday, the fifth day of June, 1913, at 11 a.m.

Manchester Steam Users' Association.—The annual report of the Committee of Management to the members of this association, just issued, states that at the close of 1912 the number of boilers under inspection and the revenue attained the highest point hitherto reached. The net surplus was £1,980. No boiler under inspection by the association has burst during the year and the committee are able to state that, at the end of 58 years, no life has ever been lost by the explosion of any boiler which the association has inspected and guaranteed as safe. Experiments have been conducted by the association for some time past, for determining the law of fatigue of metals, and it is intended shortly to publish some of the results. A careful survey has also been made of all experiments bearing on the question of the strengths of flat plates of boilers and the elasticity of steam expansion bends. Particulars of these will also be published.

THE CORROSION OF IRON AND STEEL.

IN a paper on this subject read before the Society of Chemical Industry, New York, on April 25th last, Mr. W. H. Walker said it was now six years since the electrolytic theory in its developed form was offered as a basis for the explanation of the corrosion of iron and steel, and it seemed worth while at this time to enquire regarding the accuracy of some of the conclusions to which it had led, as viewed in the light of present experience. In the first place, we had found that the factors controlling the rapidity or extent of corrosion were by no means so simple as they were at first thought to be. Many conditions which were considered of little or no importance had been found to exert a profound influence upon the reactions involved. For example, samples of iron and steel which exhibited marked differences in corrosion exposed in the normal condition in which they came from the mill failed to show any difference upon exposure, when they were planed to a uniform surface. Apparently, the mechanical strain to which the samples were subjected in the planer masked or neutralised the difference in corrosion inherent in the normal material. It was not surprising, therefore, that many conflicting results had been obtained and published from the investigators now interested in this work. Only those tests which had been carried on under identical conditions of surface finish, temperature, access of oxygen and moisture, general atmospheric conditions, &c., should be given any weight, and, even when the greatest care was taken, generalisations must be drawn with caution.

One of the conclusions reached by a consideration of the electrolytic theory of corrosion which had proved misleading was that homogeneity in the material ensured protection, while heterogeneity led to rapid attack. While this was a corollary which might be logically drawn from the electrolytic theory, and was doubtless in itself true, there were evidently other factors which superimposed themselves upon those due to differences in structure, producing a final effect contrary to that predicted. The iron of the old chain bridge at Newburyport, Mass., had withstood corrosion in a truly remarkable manner for the last 98 years, and yet it was conspicuous for its heterogeneous structure. Large areas of perfectly pure iron, free from both carbon and slag were mixed up with areas showing at least two kinds of slag, and very high carbon; yet all withstood atmospheric corrosion.

On the other hand, Burgess had shown that iron free from all contaminating elements which could segregate or produce a lack of uniformity did not withstand rusting so well as the same iron to which had been added a little manganese, or copper, or nickel. This behaviour was observed also in the case of the so-called pure irons made in an open-hearth furnace, and which were relatively free from carbon, manganese, sulphur, and other constituents prone to segregation, which had come to the writer's notice. While theoretically a very pure iron should withstand rust, there were apparently some factors present which more than offset any advantage inherent in purity. Obviously, conditions affecting the surface of the material so soon as rusting had started were important causes which had largely been overlooked and which demanded more thorough investigation.

The most important advance in this field made in recent years was a knowledge of the effect of the addition of small amounts of copper to normal open-hearth or Bessemer steel. The results of a series of tests were recently made by D. M. Buck. While these tests did not show that any steel, however poorly made, would with the addition of copper withstand atmospheric corrosion, they proved that it was the copper and not the absence of manganese and other "impurities" which was the controlling factor. Several hypotheses had suggested themselves as explaining this marked effect of copper in causing steel to resist atmospheric corrosion, but as yet none was sufficiently tangible to afford a working theory.

Rapid progress had been made in acquiring that knowledge of the relation of pigments and finished paints to corrosion which was necessary to a better protection of iron and steel. Predictions founded on the theory that a basic paint, or one containing a chromate pigment, would inhibit rusting, while one made up from lamp-black or graphite would accelerate rusting have, in the main, been found correct. The effect of the pigment upon the character of the oil film making up the

paint, however, had shown itself also to be very important. Many basic pigments, such as basic lead carbonate or zinc oxide, which in themselves inhibit, did not withstand the weather; lamp-black and graphite, on the other hand, made a very impervious and highly resistant paint film. The logical conclusion in protecting iron was, therefore, to use a basic priming coat, a second coat of a mixture of a basic pigment and a little lamp-black, and, when well dried out, to apply a lamp-black or graphite finishing coat. Experience had shown also the importance of brushing the paint well on the iron; a good paint might fail on account of poor application.

Careful tests with galvanised work showed that an even coating of zinc was the all-important factor. The common practice of clean wiping galvanised ware was fatal to durability, since the protecting layer was not metallic zinc but a thin deposit of a zinc-iron alloy. While, therefore, much had been accomplished in the way of making a more resistant base, there was still a necessity for a uniform substantial coating of spelter over the surface.

BOOK REVIEWS.

Wannan's Marine Engineer's Arithmetic for Board of Trade Examinations, by A. C. Wannan and D. Lindsay; two vols., Part I. Arithmetic, Part II. Elementary Verbals. London: Crosby, Lockwood, & Son. 8in. by 5½in.; 280 pp. Price (each) 6s. net.

These two volumes are a type of book which we should have thought by this time was extinct. It was to some extent popular some 40 years ago amongst working engineers whose early schooling in the absence of an Education Act was very defective and who desired to acquire a knowledge of elementary mechanics, but a fourth-standard schoolboy would nowadays regard the ignorance of arithmetical principles here presumed on the part of the reader almost as an insult. The professed object of the work is to prepare candidates for Board of Trade examinations for certificates of competency, and one of the authors, we note, is connected with an academy devoted specially to this class of teaching. He must, we suppose, therefore have some experience of the type of men who present themselves for this qualification, but we should not like to think the mental calibre of the type of material from which the general run of certificated marine engineers is recruited is so low as these books imply, for the examples worked out—all right in their way, since they are taken from Board of Trade examination papers—are treated as if the reader had only the most rudimentary knowledge of arithmetic, and with an elaboration of detail which would be wearisome to any first-year engineer apprentice of average intelligence. Part I. is intended as a preparatory course, and begins with simple addition, which the reader is informed "is the method of adding two or more sums together to make one sum, as the sum of 2 and 2 is 4 and the sum of 4 and 3 is 7," and that "any number of sums may be added together to make one sum." Similarly he is informed that subtraction "is the method of taking one sum from another. Example: Take 2 from 4 and 2 remains." After this follows instruction in multiplication, with respect to which the reader is informed "no one can make any headway in working out arithmetical questions unless he learns the multiplication table, more especially the 6, 7, 8, and 9 times," which portion, we may add, is reproduced for his benefit. After a few pages of this sort of stuff the reader is introduced to the actual questions relating to the strength of boilers, ship displacement, horse-power, expansion, evaporation, and the general run of matters arising out of Board of Trade rules. Few persons, however, so woefully ignorant of elementary arithmetic as the early stages of Volume I. imply are likely, in our opinion, to derive much real benefit or comprehension of the calculations associated with the working of boilers and engines on board ship, from the working out of examination questions which follow, notwithstanding the elaborate details of figuring with which they are accompanied. With a "coach" alongside him to explain and correct mistakes of reasoning, the class of reader presumed may perhaps make some progress, but to the general reader they would, we are sure, be useless, while we are equally certain that no sound knowledge of engine or boiler working is possible with such rudimentary knowledge of arithmetic, and, of course, still ruder acquaintance with scientific principles.

Introductory Electricity and Magnetism, by Carl W. Hansel, B.Sc. London: W. Heinemann. 7½in. by 5¼in.; 373 pp. Price 2s. 6d. net.

The literature of elementary magnetism and electricity is plentiful, and withal so good and cheap that we imagine the struggle for existence among text-books must be pretty keen. Certainly no special want can be said to exist for additions in this field, and it would be impossible to single this out for special praise. This, however, is in no way derogatory to the quality of the matter in the volume before us, which is well written, clearly illustrated, and amply covers the ground indicated by its title, and which is bounded at its upper limit by the Lower Certificate Examination of the Board of Education, and, needless to say, designed for class work, of which the author has had good practical experience, formerly as Demonstrator of Physics in the Imperial College of Science and latterly as Lecturer on Electrical Engineering at the Bedford Institution.

* * *

A Text-book of Thermodynamics, with special reference to chemistry, by J. R. Partington, M.Sc. (Vic.), with 93 diagrams. London: Constable & Co., Ltd. 8½in. by 6in.; 544 pp. Price 14s. net.

The range of matters dealt with, as well as the methods of treatment, under the head of thermodynamics has during recent years been considerably extended, while their practical bearing on heat-engine problems is recognised by a much wider circle in the engineering community. Its value, too, in many questions relating to physics and chemistry is evidenced by the volume before us, which pertains more particularly to this aspect of the subject. To the average engineer it probably will not appeal, as the matters dealt with are rather outside his working sphere and beyond his mathematical abilities, though to a select few the subject is an absorbing one, and studied for its abstract scientific side alone. To these the application of thermodynamics to the molecular relationships existing in what is termed "electro-chemistry" will no doubt prove extremely interesting, since it deals with much that lies on the outskirts of our present scientific knowledge and concerns many questions that lie at the root of human conceptions of the ultimate constitution of matter. The number of readers armed with the necessary mathematical ability to appreciate much that is here treated of must necessarily be few, but we trust they may be sufficiently numerous to bring some measure of commercial success to the author for the pains and erudition he has here focussed for their benefit.

* * *

Tests of Reinforced Concrete Buildings Under Load, by Arthur N. Talbot and Willis A. Slater. Bulletin No. 64 of the Engineering Experiment Station of the University of Illinois.

Besides giving the results of tests, this bulletin presents a detailed discussion of the methods and apparatus developed at the University of Illinois for measuring the stresses caused by floor loads in reinforced concrete buildings. It is shown that these stresses may be determined with a considerable degree of accuracy if care is used in making the test. The bulletin furnishes valuable information on the action of several building floors under load, and will be useful to designers of reinforced concrete structures. Copies may be obtained from the European sales agent: Chapman & Hall, Ltd., London.

BOOKS RECEIVED.

Mineral and Aerated Waters. By C. Ainsworth Mitchell, B.A. London: Constable & Co. 9in. by 6in. 227 pp. Price. 8s. 6d. net.

The Mechanical Engineers' Pocket Book. Clark & Powles. 1913 edition. 6¼in. by 4in. 704 pp. Price, 4s. 6d. net.

Transactions of the Liverpool Engineering Society. Vol. XXIII. Edited by T. R. Wilton, M.A., A.M.Inst.C.E. Published by the Society, Colquitt Street, Liverpool.

Board of Education Reports for 1913 on the Geological Survey, the Science Museum at South Kensington, and the work of the Solar Physics Committee.

HEAT ACCUMULATORS AND THEIR USE IN EXHAUST STEAM TURBINE PLANTS.*

BY A. ALISON.

THE success of most industrial enterprise depends largely upon efficiency of organisation, and the keenness of modern competition renders it imperative that every step should be taken to eliminate as far as possible all sources of waste. For many years attention has been drawn to the vast resources of the exhaust steam which is continually discharged uselessly into the atmosphere from most large steel works and collieries. The utilisation of this waste energy is the problem, the solution of which has been rendered possible by the invention of the heat accumulator and low-pressure turbine.

Before proceeding to describe the heat accumulator in detail, it may be of interest to examine, by means of the entropy chart (Fig. 1), the theoretical extent to which the recovery of power could be carried under ideal conditions. This provides the standard for the measurement of the efficiency of the means adopted in practice. On the diagram has been represented the useful work obtained per pound of

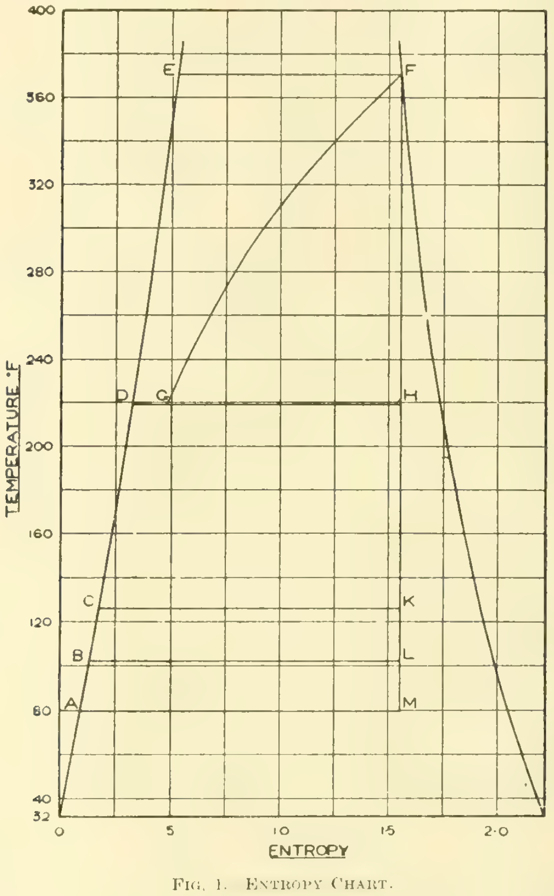


FIG. 1. ENTROPY CHART.

steam on various assumptions. In all cases the initial pressure is the same, viz., 175lbs. per square inch absolute, but the amount of expansion varies.

Case I.—The steam is used non-expansively, and exhausts against a back pressure of 17lbs. absolute. The heat available for conversion into useful work is represented by the area D E F G, and is equal to 75·7 B.Th.U. per pound of steam expended.

Case II.—The steam is expanded to a pressure of 17lbs. absolute before release, advantage being taken of the work done during expansion. The heat available in this case is represented by the area D E F H, and is equal to 169 B.Th.U., giving an increase due to expansion of 122 per cent.

Case III.—Expansion is carried to a pressure of 2lbs. absolute. The heat available is represented by the area C E F K, and is equal to 290 B.Th.U., being a further increase of 71 per cent. on the amount available on Case II.

B L and A M are the base lines when expansion is carried to a pressure of 1lb. absolute and ½lb. absolute respectively, corresponding approximately to vacua of 28in. and 29in. The results have been summarised in Table I.

* Abstract of paper read before the Junior Institution of Engineers, May 21, 1913.

TABLE I., *showing the number of B.Th.U. available for Conversion into Work per Pound of Steam. Pressure of Admission, 175lbs. per Square Inch absolute.*

	Pressure to which Expansion is Continued.	Number of B.Th.U.	Percentage, taking Case II. as 100.
I.	Without expansion	75·7	45
II.	17lbs. absolute	169	100
III.	2lbs. absolute	290	171
IV.	1lb. absolute	324	192
V.	½lb. absolute	356	211

It will be noticed that the number of British Thermal Units withdrawn from the steam whilst expanding from 175lbs. to 17lbs. absolute is only about one-half of the number withdrawn if expansion be continued to 1lb. absolute. Unfortunately, many practical difficulties arise if it be attempted to work a reciprocating engine with a very high vacuum, and experience has shown that very little gain arises from the use of vacua higher than 25in. or 26in. in the condenser, and even then it is usually found that the effective vacuum in the cylinders is several inches lower. These practical difficulties occur owing to the large volume occupied by steam at low pressures and the rapid fall in temperature which accompanies the expansion. Briefly, the objections to the use of a reciprocating engine at low pressures are: (i.) Impracticably large cylinders required; (ii.) throttling of the steam in the ports; (iii.) excessive condensation.

Turbines, on the other hand, show a somewhat greater efficiency at low than at high pressures, and the limit to which expansion can profitably be carried is determined more by the condensing plant than by the turbine itself. Numerous other advantages are attached to this type of machine, namely, compactness, low cost of installation, ease of erection, working, and maintenance, and finally the facilities for direct coupling to generators. These advantages become more apparent when it is remembered that in exhaust-steam utilisation schemes the entire turbine plant has to be erected in works already existing.

In 1894 the Hon. C. A. Parsons pointed out the merits of the turbine at low pressures, and suggested that considerable gain would result if a turbine were substituted for the low-pressure cylinder of a reciprocating engine. This idea has found practical application in marine engineering, and the combination system is now employed in several of the modern liners, in which the wing shafts are driven by reciprocating engines exhausting into a low-pressure turbine operating the centre shaft.

Intermittently Working Engines.—Several types of engine, however, by the nature of the work they are required to perform, cannot directly take advantage of the economy and increased efficiency obtained by compounding and condensation. Such engines are those which work intermittently, and illustrations of this type are afforded by reversing rolling mill engines at steel works, and colliery winding engines.

A consideration of the working of a winding engine will reveal the difficulties of utilising to the fullest extent the energy of the steam. The engine only uses steam during a part of each cycle, and, in order to rapidly accelerate the tubs, it is usual to admit steam to the cylinders throughout the whole stroke for the first few revolutions, after which the cut-off occurs earlier and earlier as the winding proceeds. Towards the completion of the wind, steam is completely cut off, and the engine gradually comes to rest. An interval of several seconds then elapses whilst the tubs are changed, and the cycle is then repeated. These stages can be traced on the indicator diagram reproduced in Fig. 2. It may be mentioned that the diagram was obtained from a continuous indicator, and in order to avoid confusion and reduce the length of the figure several of the individual diagrams have been omitted. This diagram may be regarded as being typical of each cylinder, and the wind is accomplished as follows:—

Five revolutions are made in the first 20 seconds with steam full stroke, followed by 24 revolutions in 30 seconds, with the cut-off varying from ·45 to ·2 of the stroke. The supply of steam then ceases, and the engine comes to rest in five seconds. Thirty seconds then elapse before the commencement of the next wind.

The effect of this intermittent working upon the rate of steam consumption of the engine at any instant is illustrated in Fig. 3. It will be observed that the rate of steam consumption fluctuates between the maximum and minimum values of 105,000lbs. per hour and zero.

Were a condensing plant installed it would be required to work under very disadvantageous conditions, and only inefficient results could be anticipated. The plant would need to be designed for the maximum duty, and would therefore be disproportionately large for the normal requirements. It would be expected from purely theoretical considerations that the

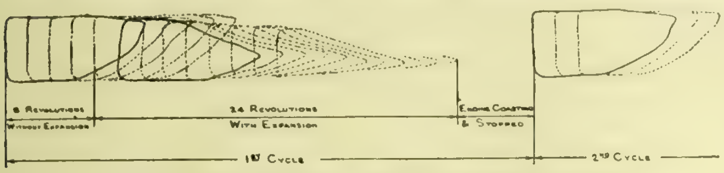


FIG. 2. TYPICAL WINDING ENGINE INDICATOR DIAGRAM.

addition of a condenser to a non-condensing engine would reduce the steam consumption by at least 45 per cent. In practice, owing to various causes, 15 to 20 per cent. appear to be the best results obtainable. Under the very difficult conditions existing in steel works and collieries, however, cases have occurred in which no gain whatever has arisen from the installation of a condensing plant.

In these circumstances, it is common to find engines of this class exhausting vast quantities of steam uselessly to the atmosphere, and the magnitude of this loss is best realised by a consideration of the average steam consumptions of the various types of engine.

	Per hour.
Winding engines	20,000lbs. to 30,000lbs.
Cogging-mill engines	15,000lbs. to 20,000lbs.
Rail-mill engines	25,000lbs. to 30,000lbs.
Plate-mill engines	40,000lbs. to 60,000lbs.

The problem of utilising this waste heat was solved in the year 1901 by Prof. Rateau, of Paris, and at the present time no less than 400,000 b.h.p. is being recovered from exhaust steam.

The Accumulator.—The object of the system introduced by Prof. Rateau is to obtain a regular supply of steam in place of the steam intermittently ejected from the primary engine. This aim is attained by passing the exhaust steam into a suitable heat accumulator, whence a continuous supply of steam is withdrawn to operate a low-pressure turbine. Experiment shows that if water be enclosed in a vessel, any space existing above the surface of the water will become filled with vapour, in quantities depending upon the temperature of the water. A state of equilibrium will finally be reached when the space is saturated with vapour, and any decrease in temperature will cause a resultant condensation of a portion of the vapour, whilst any increase will cause further evaporation to take place. For every temperature there is a corresponding

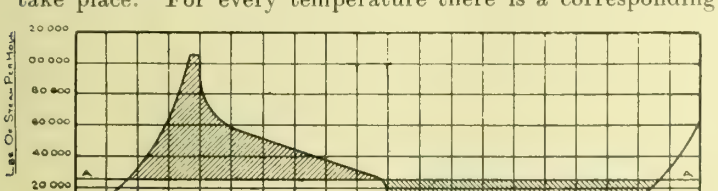


FIG. 3.—STEAM CONSUMPTION DIAGRAM.

maximum vapour pressure, and vice versâ. These relationships are tabulated in the saturated steam tables. This is the principle upon which the heat accumulator is based.

The water-type accumulator consists essentially of a vessel partially filled with water, into which the exhaust steam from the engines is passed. The steam is condensed and the temperature of the water raised, with a resultant increase of the vapour pressure in the steam space above the surface of the water. The supply of steam to the exhaust-steam turbine is drawn from the steam space, and it follows that, whilst the main engines are at rest, a continuous quantity of steam can be delivered to the turbine at a gradually diminishing pressure. The extent of the reduction in pressure within the accumulator depends upon the amount of steam supplied to the turbine during the interval when no further supply of steam is forthcoming from the engine. This interval is termed the "stop," and is usually about 30 seconds in rolling mill work, and 60 seconds in colliery work, although accumulators have been designed, when necessary, to bridge considerably longer periods than this. It sometimes happens that the main engines stop working for longer periods than the accumulator has been designed to accommodate. In order to render the turbine independent of the engines in these circumstances, a supply of live steam is admitted to it through a reducing valve. The reducing valve is automatic in action, and only comes into operation when the pressure in the accumulator falls below some predetermined point. Economical results, however, cannot be obtained in this way, and when the main engines are liable to have periods of abnormal stoppage, a mixed-pressure turbine should be installed. The steam consumption is about 5 per cent. better when working on reduced live steam than when on exhaust steam; this gain arises from the slight superheat caused by wire-drawing at the reducing valve.

Referring once more to Fig. 3, the horizontal line A A represents the mean steam consumption of the engine, and is the amount available, neglecting losses, for use in the turbine. The function of the accumulator is to absorb the surplus steam represented by the shaded area above the line A A whilst the engines are working, and to restore it to the turbine when the engines are stopped. In this way a uniform supply of steam is maintained to the turbine.

The variation in pressure that occurs within the accumulator can be recorded by means of a gauge connected to the steam pipe of the turbine. A chart obtained in this manner is reproduced (Fig. 4), and it will be observed that the pressure fluctuates between 15lbs. and 17lbs. absolute. It must be

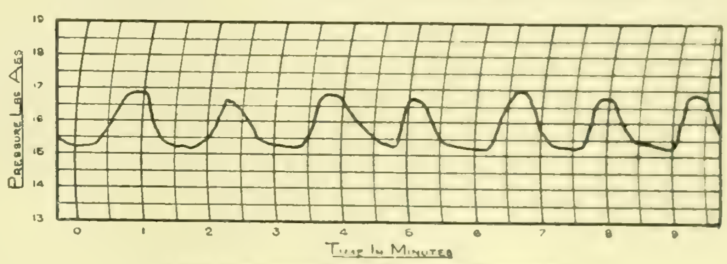


FIG. 4. ACCUMULATOR PRESSURE DIAGRAM.

borne in mind, however, that both the pressure range and maximum and minimum values of the pressure within the accumulator can be arbitrarily fixed and given any assigned values. The pressure in the pipe line from the main engines seldom exceeds $\frac{1}{2}$lb. per square inch above the pressure in the steam space, and can be regulated by means of adjustable relief valves fitted in the pipe line and upon the accumulator shell. These valves can be set to ensure the pressure never exceeding some predetermined amount, and the whole plant can therefore be designed to work at pressures below atmospheric. Such conditions should only be resorted to in circumstances where the main engines are normally overloaded, a state when any increase of back pressure would be detrimental. On the other hand, if greater power be required from the turbine plant, it can be obtained by deliberately raising the initial and final pressures in the primary engine. The steam consumptions of a turbo-generator per electrical horse-power hour at three different initial pressures are tabulated in Table II.

TABLE II.

	Vacuum at Outlet of Turbine	Pressure at Admission, [illegible]			
		29·4	14·7	7·1	
Surface condenser	27.5in	20·5	26·5	36·4	Consumption
Jet condenser	26in	23·6	31·8	47·5	per e.h.p.
Ejector condenser	24in.	26·5	36·4	61·8	hour

It will be noticed that with a pressure in the accumulator of slightly over 7lbs. absolute, the steam consumption of the turbine is only 36·4lbs. per electrical horse-power hour when

the vacuum in the condenser is 27·5in. The data also emphasize the importance of maintaining a good vacuum, and to do this it is necessary to reduce air leakage into the system as much as possible. This is, naturally, more difficult to do when the whole plant is working at pressures below atmospheric.

Accumulator Capacity.—The conditions within an accumulator do not correspond to a state of exact thermal equilibrium, and it would be difficult to obtain an accurate expression for the capacity required. Viewed from a practical standpoint, it is ample to formulate an approximate expression, and the following calculations must be regarded in that light. The weight of steam to be stored by the accumulator is equal to the weight of steam from the main engines after deducting the

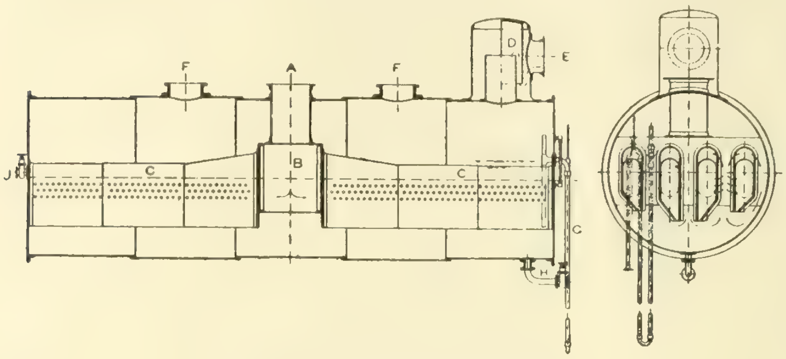


FIG. 5.—RATEAU HEAT ACCUMULATOR.

weight simultaneously passing to the turbine, and can be obtained from a knowledge of the hourly steam consumption of the turbine and the duration of the interval for which the steam supply from the main engine ceases.

If W_1 = Steam consumption of the turbine in pounds per hour,

S = duration of the "stop" in seconds,

then the weight of steam to be stored by the accumulator in one cycle of operations is equal to

$$W_s = \frac{W_1 S}{3600} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \text{(i.)}$$

The capacity of an accumulator can only be defined with reference to the greatest back pressure which may be imposed on the main engines. It will be in accordance with current practice if the accumulator be designed so that the pressure within it shall fluctuate between the limits of 2lbs. above to 1lb. below atmospheric pressure, this giving a range in temperature of about 10° Fah. If, therefore, W be the weight of water required in the accumulator in order that the quantity of steam (W_s) found by equation (i.) above, may be stored without exceeding these limits, the following equation must hold :—

$$W = \frac{W_s L}{(t_2 - t_1)} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \text{(ii.)}$$

where L is the latent heat per pound and $(t_2 - t_1)$ is the temperature range. L may be considered to have a mean value of 966 B.Th.U., and $(t_2 - t_1)$ has been fixed at 10° Fah. Inserting these values in equation (ii.), and substituting for W the expression found in equation (i.), the final result is obtained that

$$W = \cdot 027\ W_1 \times S \ \ldots\ldots\ldots\ldots\ldots\ldots \quad \text{(iii.)}$$

From this relationship it would appear that the size of the accumulator is independent of the time for which the main engines are working, but is directly proportional to the time for which they are stopped. In practice, however, this is not the case. These calculations have been made on the assumption that the steam is instantaneously absorbed on entering the accumulator, but it is clear that if the "stop" is at all large, compared with the time during which steam enters the accumulator, the rate of absorption will require to be very considerable. Owing to the low conductivity of the water, it is probable, in these circumstances, that the pressure would tend to rise above the permissible limit, thus involving considerable loss of steam at the relief valves. This would not be because the water in the accumulator was insufficient to ultimately absorb the steam, but because some time must elapse before a state of thermal equilibrium could be established. It is therefore imperative to provide some agitating agency in order to produce a thorough circulation of the contents of the accumulator and to ensure that the water and steam are rapidly and intimately mixed. Except when working under the most favourable conditions, it is probable that a considerable proportion of the water does not take part in the storage operation, and it is advisable to allow for this by designing the accumulator to contain a greater bulk of water than the weight theoretically required (equation (iii.)).

In the majority of works there is generally a certain proportion of the machinery which works continuously, whilst other sections work intermittently. In these circumstances it is not uncommon to find the combined exhausts of the engines conveyed to the accumulators, and this practice often proves more economical than installing separate condensing plants for the continuous, and accumulators for the intermittent, sections. It follows that where numerous exhausts are combined in this manner there may be periods when the rate of steam supply to the accumulators will be very high. This will arise from the fact that many engines working intermittently may be simultaneously exhausting steam to the accumulators, necessitating a greater storage capacity than would otherwise be required. To arrive at a decision as to the weight of water actually required in the accumulator involves, therefore, a consideration of various practical points, and is in a measure indeterminate. In practice it seems that 200lbs. to 250lbs. of water are often allowed per pound of steam.

Types of Accumulator.—The earliest form of Rateau accumulator consisted of a vertical cylindrical vessel, in which shallow cast-iron trays containing water were arranged. The trays were placed one above the other, and the exhaust steam, which entered at the bottom of the vessel, was forced by means of suitable baffles to pass repeatedly to and fro over the surface of the water. A considerable bulk of metal and water was contained in the accumulator, and the arrangement adopted allowed a very great cooling surface to be exposed to the incoming steam without rendering the apparatus unduly large. Where floor space is limited, this type of accumulator has some advantages, by reason of its compactness, but, nevertheless, it appears to be superseded by the more recent design of water accumulator.

Water-type Accumulators.—The Rateau water-type accumulator (Fig. 5) consists of a mild steel shell partially filled with water, and its action is extremely simple. Steam enters at A, whence it passes into the central distributing chamber B, to each side of which are connected two pairs of tubes C. These tubes are perforated with three or more rows of holes along their adjacent sides only. The water level within the accumu-

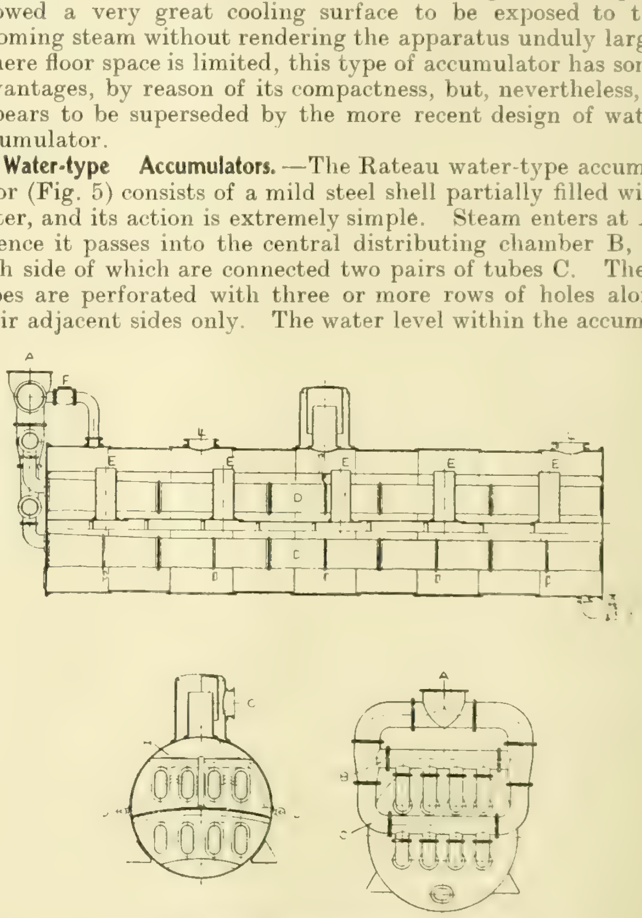


FIG. 6.—DOUBLE COMPARTMENT ACCUMULATOR.

lator is normally from 15in. to 18in. above the topmost row, and is maintained constant by a water-level regulator G. On the admission of steam, the water within the tubes is depressed until some of the holes are uncovered, thereby allowing steam to escape into the surrounding water. The steam in its ascent induces a circulation, as indicated by the arrows in the cross-sectional view, and after a very brief interval the whole mass of water within the accumulator is in a state of motion. This

ensures a thorough intermixing of the steam and water, and gives a resultant high absorption capacity to the accumulator. The steam outlet dome is at E, and D is a semi-circular baffle arranged to intercept any moisture suspended in the steam. Mountings for relief valves are at F. Scum can be periodically withdrawn at J. H is a washout valve. A design such as is shown would be suitable for a shell 8ft. 6in. to 9ft. 6in. diam. and 30ft. to 45ft. long.

Double-compartment Accumulator. — In cases where the accumulator is required to contain a very large quantity of water, the difficulty of rapidly promoting a thorough circulation of the entire contents becomes greater and necessitates some modifications to the interior (Fig. 6). The shell is divided longitudinally by a diaphragm, and in each of the two compartments so formed four oval tubes D are arranged. These tubes are perforated, as in the previous design, along one side only, and the relative water level in each compartment is maintained the same. Steam enters at A, and passes into the bus-pipes B, C, connected to the tubes D, in each compartment. The steam spaces of the upper and lower compartments are connected by the flues E, through which the steam from the lower ascends. Two baffles H extend along the length of the shell, and intercept any water that may be sprayed into the steam space. The outlet dome is at G. F is a non-return valve, and prevents the reflux of water should the main engine coast or be stopped for a considerable time, and a vacuum thus be formed in the pipes. L, L are mountings for relief valves. Each compartment can be emptied by the washout valves J. This design of accumulator is suitable for a shell 11ft. 6in. diam. by 45ft. long, and would be capable of maintaining a supply of steam at the rate of 70,000lbs. per hour when the interval to be bridged is one minute.

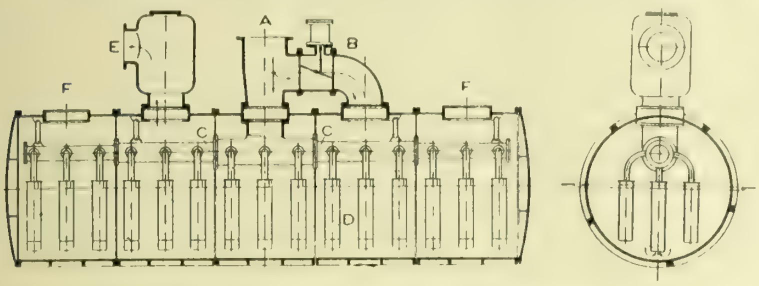


FIG. 7.—RATEAU-MORISON HEAT ACCUMULATOR

It may be mentioned here that the condensation losses due to radiation, &c., in an efficiently lagged accumulator do not exceed 1 per cent. of the total steam. The losses in pipe lines several hundred feet long may amount to 10 per cent., but this figure includes any water that may pass from the high-pressure steam pipes through the engine, and also any condensation that occurs in the main engine itself.

The Rateau-Morison Accumulator.—The accumulator patented by Mr. D. B. Morison possesses many distinctive features (Fig. 7). The perforated steam tubes of the Rateau type are replaced by a number of specially designed nozzles D, capable of promoting and maintaining a most efficient circulation of the water within the accumulator. To ensure efficiency, the conditions to be fulfilled by a nozzle are two-fold : (*a*) That it shall promote a thorough circulation of the water in the accumulator ; (*b*) that the intermixing of the steam and water shall be accomplished with the minimum resistance to the passage of the steam.

These conditions are satisfied by the design of nozzle illustrated diagrammatically in Fig. 8. The nozzle proper is at N, and is surrounded by a guide tube D, and when submerged is about 9in. below the surface of the water. Steam emerges in thin films from the narrow slot in the upper portion of each radial arm, and induces an upward flow of water within the guide tube, meanwhile exposing a large surface in contact with the water. A considerable velocity is attained by the ascending column of water, and very little variation is found to exist between the temperature of the water at different places in the accumulator after a normal period of absorption. Each nozzle is designed to give a maximum efficiency when passing a definite quantity of steam, and if this quantity be exceeded, the back pressure on the main engines will be increased and the action of the nozzle rendered less efficient. The amount of steam from the engines varies from time to time, and, in order to ensure that the nozzles are always working under the most favourable conditions, the steam that is in excess of that for which they are designed is automatically by-passed to the turbine or into the steam space of the accumulator. The normal resistance of the nozzles when submerged is about ¼lb. per square inch.

Referring to Fig. 7, steam enters at A, and is simultaneously passed to all the nozzles through the central distributing pipe C, and by-passed through the by-pass valve B into the steam space. This valve is of special construction, and comes into operation when the pressure in the mains tends to rise above that for which the nozzles are constructed.

Absorption is greatly improved if during the interval for which it takes place the pressure in the steam space be maintained slightly higher than the saturated vapour pressure, corresponding to the temperature of the water in the accumulator. In this way ebullition is retarded and the whole energy of the steam is applied to raising the temperature of the water, and not to simultaneously heating and evaporating it. This relative difference in pressure can be obtained by constructing the by-pass valve so that it is never completely closed. By this means the pressure in the steam space is always equal to that in the main engine exhaust pipes, and is therefore slightly higher than it would otherwise be.

Oil Separation.—It is of primary importance that no oil be present in the accumulator, as both experiment and practice prove that the presence of even relatively minute quantities on the surface of the water has a marked retarding action on the regenerative process. Oil is always suspended in the exhaust steam from the main engines, and to eliminate it as far as possible an oil separator should be fitted in the pipe line between the accumulator and engines. The steam, however, which enters the accumulator is condensed and re-evaporated, causing the accumulator itself to become a most efficient oil separator. It follows that any traces of oil that are not removed by the separator will by a cumulative process ultimately form a scum on the surface of the water and prejudicially affect the rate of regeneration. Until the introduction of the Morison accumulator it was customary to periodically draw off this floating matter by means of a scum trough and cock fitted at each end of the shell. The latest design of Rateau-Morison accumulator, however, embodies a device which renders scumming continuous and automatic. The top of each guide tube is formed into a cowl in order to cause the discharge from each tube to be in the direction of the length of the shell. The effect of this is to set up a ripple on the surface of the water, which washes any floating impurities into a collecting chamber at one end of the shell, whence they are removed. This chamber has been omitted in the illustration. Another noteworthy feature of this type of accumulator is the design of shell employed. The shell consists entirely of

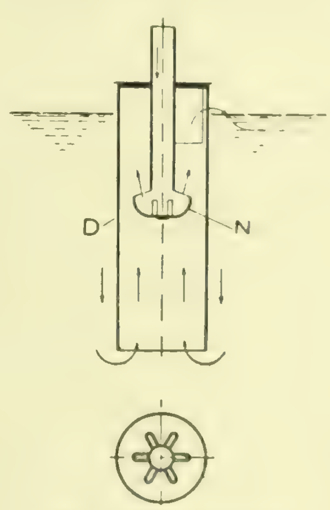


FIG. 8.—CIRCULATING UNIT.

cast iron, and is constructed of curved sections bolted together —a form of construction which affords many facilities for transport and erection. The remaining fittings and accessories consist of an outlet dome E, relief valve and manhole mountings at F, a water gauge glass, water level regulator, and a washout.

Scrap Iron Type. — An accumulator of this construction consists of a disused boiler shell or any cylindrical vessel

filled with old rails closely stacked together. The exhaust steam is passed through the numerous interstices and is condensed by contact with the rails. On the cessation of steam from the main engines a regenerative process occurs. Satisfactory results have been obtained in this way, and it is interesting to note that this type was adopted in the first exhaust steam utilisation plant installed in Great Britain.

Gasholder Type.—For relatively small plants it has been found possible to use an accumulator similar in design to the familiar gasometer. In these circumstances the steam is not absorbed and regenerated, but is stored in a receiver. The volume of the holder would of necessity require to be very great for an installation of any magnitude, and it is doubtful if satisfactory results could be obtained on a large scale. Moreover, considerable loss must occur due to radiation, and it does not appear improbable that the wear due to the rapidity of action and the inevitable corrosion would render the cost of maintenance high.

Existing Installations. — As a matter of general interest, particulars of several existing installations are inserted, and illustrate the application of the Rateau system of exhaust steam utilisation to (*a*) steel works; (*b*) collieries. In all cases the heat accumulator forms an essential feature of the plant.

Steel Company of Scotland—Hallside Works.—Installation by Mr. P. J. Mitchell. The primary engines consist of: One cogging engine, two cylinders, 40in. diam. by 5ft. stroke. One finishing engine, cylinders 42in. diam. by 5ft. stroke. Two mill engines working 14in. and 18in. mills. One 10-ton and one 4-ton steam hammer.

The available supply of steam after allowing for losses due to condensation, &c., was estimated to amount to 41,000lbs. per hour. It was therefore decided to install two 450 kw. low-pressure turbo-generators with a voltage of 230. The turbine has an output of 700 b.h.p. at 1,500 revs. per minute when supplied with steam at atmospheric pressure and exhausting to a vacuum of 27in. Under these conditions the output of the turbine is 65 per cent. of that theoretically possible with steam expanded between these limits of pressure. The space occupied by the turbo-generator is 22ft. by 6ft.

The exhaust steam from the main engines is passed into a receiver prior to entering the accumulator, and this reduces the violent shocks that would otherwise occur. A water-type accumulator, 11ft. 6in. diam. by 35ft. long, is used, and is designed to give full load when bridging stops of 40 seconds' duration. The main engines, however, are sometimes standing for roll changing, &c., for considerably longer periods than this, and this necessitated the fitting of a live steam supply to the turbine to furnish steam at reduced pressure at these times.

It was found that on stopping the main engines one turbine could be run for six minutes independently of the live steam supply, at a load of 1,700 amperes, and at the end of 9 minutes an output of 500 amperes was still given, although the pressure in the accumulator was reduced to a 10in. vacuum.

Dominion Iron and Steel Company, Sydney, Cape Breton.—At this works there are at present four accumulators, 9ft. 6in. diam., and 40ft. long, and each is designed to receive 75,000lbs. of steam per hour and to bridge periods of 30 seconds. The combined capacity of the accumulators is therefore 300,000lbs. of steam per hour, and this steam is utilised to generate 8,000 kw. of electrical power. At the present time two additional accumulators are in course of erection. These are each 9ft. 6in. diam., and 30ft. long, and together are capable of dealing with 280,000lbs. of steam per hour when bridging engine stops of 10 seconds.

Penrikyber Colliery.— The exhaust steam at this colliery is obtained from one winding engine, one fan engine, and one engine driving an air compressor. The steam is conveyed to four accumulators, each 7ft. diam. and 30ft. long. The turbine installation consists of two Rateau turbo-alternators, one being a 500 kw. low-pressure set, and the other a 1,250 kw. mixed-pressure set. The latter machine is capable of giving the full output on high-pressure steam alone, and 750 kw. on low pressure steam. When working under normal conditions on full load, 30,000lbs. of steam at 16lbs. per square inch absolute are used to supply 750 kw., and the balance of 500 kw. is obtained by the use of high-pressure superheated steam at a pressure of 140lbs. per square inch. The over-all steam consumption under these conditions is about 33lbs. per kilowatt-hour.

The foregoing illustrations refer to installations in which the exhaust steam is utilised for obtaining electrical power. The turbine, however, is equally well adapted for the direct driving of rotary air compressors and blowers, and is extensively applied for this purpose in collieries and steel works.

Conclusion. — Reviewing the subject briefly, the introduction of the heat accumulator has rendered it commercially possible to recover a considerable amount of power that would otherwise be wasted. This power is obtained without any increase in the steam and fuel consumption, and, in the case of a non-condensing engine, practically without any alteration to the existing plant. Even in the case of an engine already working with a condenser, considerable gain may be anticipated by the addition of a low-pressure turbine. The turbine is at present unrivalled as an agent in the conversion of the energy of steam into work, and, when used in combination with a reciprocating engine, the results obtained for a given steam consumption are unequalled by any other system of compounding. Moreover, there appears to be a marked objection amongst colliery engineers to the introduction of any complications to the winding machinery itself, and this fact alone renders it improbable that all winding engines will be fitted with condensers in future, aside from considerations of the relative inefficiency of such an arrangement. On the other hand, the addition of an exhaust steam plant, whilst affording a great source of gain, does not in any way complicate the existing machinery, nor is the operation of the primary engine suspended in the event of a breakdown occurring in the secondary motor.

Against these advantages must be set off the capital cost of the turbine installation, and the cost of maintenance and repairs. A good vacuum is necessary if the best results are to be realised, and this can only be obtained if a copious natural supply of cooling water is available, or by incurring the additional expense of a cooling plant. Even if it be necessary to adopt this latter alternative the results obtained in practice amply justify the outlay, and the manifold advantages of the system of exhaust steam utilisation invented by Prof. Rateau, quite outweigh any of the foregoing objections.

In conclusion, the writer wishes to express his thanks to Mr. P. J. Mitchell, the introducer of the system into this country, and to Mr. D. B. Morison, the patentee of the Morison accumulator, for permission to publish the information contained in this paper and for the loan of some of the illustrations.

Institution of Electrical Engineers' Awards.—The Council of the Institution of Electrical Engineers have awarded two Salomons Scholarships of the value of £50 each, one to Mr. Grahame George Dawson, of University College, London; and one to Mr. Robert Burleigh, of the City and Guilds (Engineering) College, South Kensington; and a David Hughes Scholarship of the value of £50 to Mr. John Harsant Lee, of King's College, London. The following premiums for papers have been awarded by the Council this year. The Institution Premium, value £25, to Mr. A. E. Hadley, for his paper, "Power Supply on the Rand." The Ayrton Premium, value £10, to Mr. F. H. Whysall, for his paper, "The Use of a Large Lighting Battery in connection with Central Station Supply." The Fahie Premium, value £10, to Mr. A. J. Aldridge, for his paper, "Practical Application of Telephone Transmission Calculations." The John Hopkinson Premium, value £10, to Dr. E. Rosenberg, for his paper, "Self-synchronising Machines." The Kelvin Premium, value for this year £21, to Messrs. C. C. Paterson, E. H. Rayner, and A. Kinnes, for their paper on "The Use of the Electrostatic System for the Measurement of Power." The Paris Premium, value £10, to Mr. J. S. Peck, for his paper, "Earthed *v.* Unearthed Neutrals on Alternating-current Systems." An extra premium, value £10, to Mr. M. Solomon, for his paper, "Yellow Flame Arcs." An extra premium, value £5, to Dr. A. C. Michie, for his paper, "The Formation of Deposits in Oil cooled Transformers." Students' premiums, value £10, to Mr. H. R. Constantine, for his paper, "Time Limits," and to Mr. J. Hacking, for his paper, "Phasing Out of Alternating-current Apparatus." Students' premiums, value £5, to Mr. C. H. Goulden, Mr. S. N. C. K. Whitehead, Mr. P. Grice, and Mr. A. T. Robertson, for their papers.

VAPORISERS AND COMBUSTION CHAMBERS OF OIL ENGINES.

Two patents have just been granted to Messrs. Crossley Bros., Ltd., Openshaw, Manchester, and Mr. W. Webb, for improvements in the vaporisers and combustion chambers of oil engines. The vaporiser is shown in Fig. 1, and is separated from but is always in open communication with the cylinder of the engine by means of a contracted neck. It is sometimes arranged with the air inlet and exhaust valves in the water-jacketed portion of the vaporiser, and the improvement consists of so arranging the various parts of such a vaporiser that the unwater-jacketed portion of the vaporiser and the oil injector are at two opposite sides of the water-jacketed portion of the vaporiser, the air admission valve being placed opposite the contracted neck so that the air on entering sweeps across the whole vaporiser on its way to the cylinder. In some cases, and particularly in vertical engines, the air admission valve and the exhaust valve are arranged side by side in the water-jacketed portion of the vaporiser opposite to the contracted neck. Referring to the illustration, the cylinder of the engine is shown at A, the piston at B, the water-jacketed portion of the vaporiser at C, the unwater-jacketed portion of the vaporiser at D, the contracted neck at E, the oil injector at F, the air admission valve at G, and the exhaust valve at H.

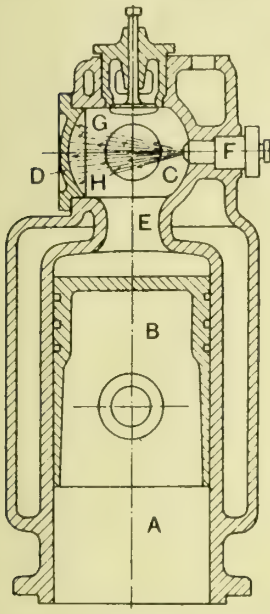


FIG. 1.—CROSSLEY'S VAPORISER FOR OIL ENGINES.

The combustion chamber is shown in Fig. 2 and is applicable to horizontal engines working on the 4-stroke cycle and in which the oil is only introduced into a combustion chamber or vaporiser and combustion chamber separated from but communicating with the working cylinder at all times by means of a contracted neck. The oil is introduced on the compression stroke. The contracted neck is arranged at the lowest part of the cylinder and the exhaust valve placed at the lowest part of the combustion chamber, so that any lubricating oil or fuel oil tending to lie in the working cylinder or in the combustion chamber will be swept out through the exhaust before it can accumulate to any material extent. With the same object in view the restricted passage and the exhaust valve may be placed even slightly lower than the bottom of the cylinder and of the combustion chamber so as to further prevent any accumulation of oil. The exhaust valve is arranged with its spindle in a vertical position and the valve is placed in such a position that the contracted neck is between it and the cylinder. In the same part of the combustion chamber immediately above and on the same vertical axis as the exhaust valve is placed the air inlet valve, which is a separate valve and opens independently into the combustion chamber. This chamber is water jacketed. Referring to the illustration, the combustion chamber is shown at A, the vaporiser cap at B, the contracted neck at C, the piston at D, the working cylinder at E, the exhaust valve at F, and the air admission valve at G. In this illustration the contracted neck C is shown at the lowest part of the engine cylinder and so also is the exhaust valve F. The vaporiser cap B is shown opposite the contracted neck C, but it may be arranged at any other convenient part of the combustion chamber. The oil fuel injector (not shown) is arranged at any convenient part of the combustion chamber or vaporiser.

GROWTH OF A COMMERCIAL RESEARCH LABORATORY.

THE development of the physical and chemical research laboratory of the General Electric Company in the 12 odd years of its existence shows many features of general interest. In 1901, Prof. W. R. Whitney, of the Massachusetts Institute of Technology, was engaged to organise a department of chemical and physical research. By the middle of that year the force employed had reached the number of five and this soon was increased to a dozen, but it was three years before Prof. Whitney left the Institute and devoted his entire time to this project.

The first laboratory was in one small room in an old building, but at the end of the first year it was necessary to remove to larger quarters. About the time Prof. Whitney took complete personal charge of the work, the number of assistants had reached 35 and it was necessary to move again. Then the present quarters were secured, consisting of some 40 rooms, each about 20ft. by 20ft. These all have good natural and artificial illumination and are piped for water, illuminating gas and hydrogen, with nitrogen, oxygen, steam, suction and compressed air in a few rooms. A complete system of wiring makes electrical energy available in each room with potentials up to 6,600 volts, currents up to 200 amperes, and power up to 150 kw. For furnishing this supply one room is equipped with some 15 motor-generator sets of up to 200 h.p. variously arranged to secure the necessary range of voltages and frequencies. Of course, a machine shop and supply room are adjuncts, and there is a special library (distinct from the main technical library of the company in another building).

The department will move again shortly, for the company is erecting a seven-storey brick building, at a cost of about £60,000, exclusively for housing this department and the standardisation laboratory. One of the features of this building will be an assembly room for the accommodation of general staff discussions which are held for an hour and a half on each Saturday morning. Among the hundreds of investigations which have been brought to successful conclusions, some have stood out because of magnitude and importance of commercial results. Among these there should be mentioned first, perhaps, the production of

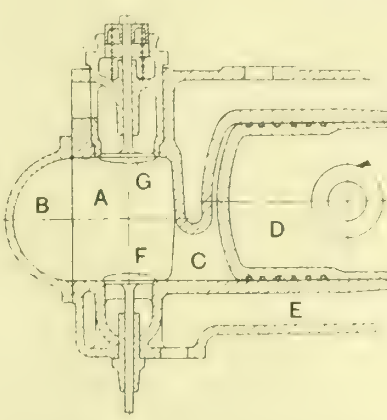


FIG. 2.—CROSSLEY'S COMBUSTION CHAMBER FOR OIL ENGINES.

ductile tungsten for incandescent-lamp filaments. After that in close order come the development of the metallised-carbon lamp filament, the mercury-arc rectifier, the magnetic-arc lamp, silicon steel for transformer cores, special-alloy resistance wires, new electric furnaces and innumerable furnace products, the improvement of insulating materials and metallurgical operations, &c.

It is believed by the enthusiastic workers in this laboratory that the conditions here for successful investigation are ideal; each man is one of a group marked by its training and enthusiasm for chemical and physical study. The resources of the company back of the laboratory are varied and great, and it is assumed that, if the probable results of an investigation are sufficient to warrant its pursuit, then time and money are little considered. Some £40,000 is now spent annually on the laboratory. One factor which has contributed much to the satisfaction with which men have pursued important investigations is the willingness of the company to publish his results at the proper time. This is done through papers before various technical societies by the principal investigators themselves. Instances of this are seen in the announcements which have been made from time to time of the use of boron for producing homogeneous copper castings, the production of ductile tungsten, the derivation of laws for conduction and convection transfer of heat from solids to fluids.—"Engineering News."

APPLICATION AND PRODUCTION OF DIE CASTINGS FOR AUTOMOBILES.*

BY WALTER BETTERTON.

THE great development of the automobile industry in recent years has naturally stimulated the production of component parts in such a manner that they shall be cheap in cost and accurate in finish to ensure economical assembling and rapid interchangeability. We thus find a great increase in the demand for such tools as multiple spindle drilling, boring, milling, bar automatics, and semi-automatic turning machines. Therefore, it is but natural that attention should be directed to the production of die-castings for the purpose of eliminating machine work wherever possible. Even in these days of great changes it may seem a little startling to suggest that parts which are now generally made in cast iron and brass may one day be die-cast. For my own part, while I do not suggest that there is to be an immediate revolution in this respect, I do say that rapid improvements in this direction are even now taking place, which must be taken into consideration by automobile engineers and manufacturers of machine tools, as there can be no doubt that die-casting will in future take an increasingly important part in the motor industry. It is a little singular, in view of the great strides that have been made in America in methods of die-casting, that so little should have been done in this country. I propose, therefore, to consider this evening the present stage of development of this interesting method of production, to deal with the problems that have been and yet remain to be overcome in making it a commercial success, and to indicate its scope and possibilities for the future.

The origin of die-casting is obscure, although probably the first machine involving the general principle was that invented

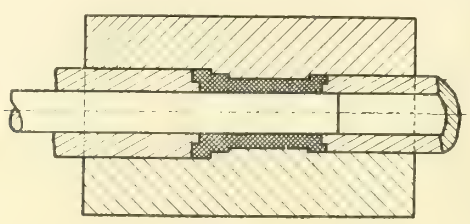


FIG. 1.

by Bruce in 1838 for casting type, and of which the linotype machine is the lineal descendant. It is also probable that the phenomenal success of the linotype machine directed attention to the possibilities of this method for other purposes. Die-casting, as we are considering it, seems to have been commenced by the Franklin Manufacturing Company, of New York, about 20 years ago, but when this firm entered the automobile industry about 1904, they found by experiment that the only parts for which the process could then be profitably employed were connecting-rod bearings, for which, however, it was found to be ideal. Since then, great strides have been made in America, but in England, except for oil pump bodies, and one or two other minor parts, the process seems to have been neglected, and in some instances actually dropped, because of the peculiar difficulties of the process and the limitations in the matter of the metals and alloys which it has hitherto been possible to subject to this process.

The method of making a casting is, generally speaking, as follows: A suitable steel die or mould is made, which is built up in segments. The shape of the article is first of all engraved in the segments which form practically indestructible steel dies capable of producing an almost unlimited number of accurately-finished castings. The die is held firmly together in the machine, and molten metal is forced into the die, the pressure being provided either by a pump, which acts directly upon the metal, or by air pressure applied to the top of it, or by a head of molten metal. When the casting has cooled down to a certain point, the mould is opened and the casting ejected. If the die is too hot, it must be cooled by air blast or other means in readiness for the next operation. The temperature of the die is very important and should be maintained constant, or the expansion of the die will prevent uniformity in the finished castings. This operation is generally carried out in "hand" machines, that is, machines operated manually. There are, of course, automatic machines in use which are far superior for the production of uniform castings, because it is not then possible for the operator to vary the conditions.

The greatest advantage of die-casting is that the castings produced are completely and accurately finished when taken from the dies. By the word "completely," I mean that absolutely no machining is required after the piece has been cast; and when I say "accurately," I mean that all the pieces will come out of the die exactly alike, and if the dies are carefully made, there should be no difficulty in producing castings accurate to within one-thousandth of an inch of all dimensions, whether outside dimensions or diameters of holes. All holes are included when casting and come out as smooth, if not smoother than if they were reamed. Threads external and internal and of any desired pitch above 24 to the inch may be cast; if smaller, it is not desirable to cast them. In the case of tapped holes below $\frac{3}{16}$in. diam., only the tapping size hole should be cast. Oil grooves may also be cast in bearings. A special feature of this process is that where necessary, brass, steel, or other metal, pins, bushes, tubes, &c., can be cast in, so saving the trouble and expense of fitting.

Without overlooking the fact that I have said that die-castings require no fitting or machining, and are ready for immediate assembling, I think that in the case of gear centres, where extreme accuracy is required, it would be an advantage to hand ream the holes in a jig. This would be quite an inexpensive operation. It might also be advisable to machine the joint faces of such parts as motor-cycle crank cases. At the same time, if the castings are good ones, this should not be necessary.

Manufacturers of accessories have found that die-casting, especially of the harder alloys, is well adapted to such parts as timer bodies, the framework of magnetos, lighting systems, and taximeter bodies. In addition to bearings, which are now so commonly die-cast, the following parts used in automobile construction are suitable for the process, and indeed, are already so made in America more so than in this country: Oil and water pump bodies, hub caps, carburetter parts, petrol filters and float chambers, motor-cycle crank cases, petrol filters, and carburetter parts and so on.

Generally speaking, a part should not be considered for die-casting if only few pieces are required, as the cost of the die would be prohibitive. It may sometimes occur, however, that because of the large amount of accurate work to be performed on the part, it would be economical to make a die for a comparatively small number of parts and die-cast them. A rough part that would require little or no machining should not be die-cast, because, weight for weight, die-casting metals cost more than cast iron or steel. Furthermore, die-casting machines cannot produce parts as rapidly or of such hard metals as the press or the automatic screw machines. For this reason a part that must necessarily be made of brass or steel cannot be die-cast, although mixtures approximately equal in strength to iron and brass are readily die-cast.

It should be clearly understood that die-castings are not made in competition with screw machine work, presswork, or cheap stampings which require only a small amount of machinery. Roughly speaking, the drawbacks to the process are the cost of the dies and the cost of metals. The latter runs directly proportional to the number of parts, while in the former is inversely proportional to the number, becoming so small for a large number as to be insignificant. The metal cost of small parts, however, is low, if account is taken of the high cost of machining cheaper metals that cannot be die-cast. From what has already been said, it is clear that there are three questions to be considered before deciding to die-cast any particular part. First, can the piece be made in brass or cast iron, and if so, can a die-casting metal be substituted? Secondly, does the quantity justify the expense of making dies? Thirdly, would the saving by eliminating machining make it desirable to cast the part in question?

It is essential that designers should have sufficient knowledge of the process of die-casting to enable them to prepare designs which can be cast in the simplest and most easily operated dies, with the view of course to cheapness. Although die-casting machines vary greatly in their construction and mode of operation, the design of the various dies involve the same principle; therefore it is only the die which need enter into one's calculations when designing parts to be die-cast.

* Paper read before the Graduates' section of the Birmingham Branch of the Institution of Automobile Engineers, April 8th, 1913.

Bearing in mind that all die-castings are made by forcing molten metal into the mould, or die, the first point to be noted is that complications usually arise from the necessity of removing the casting when finished from the die. In the case of a casting containing cores, it cannot be removed as when sand-casting, nor can outside cores be used in order to take care of projecting or undercut parts. This should be done with sliding pieces, pulls, &c., in the die itself, and naturally this introduces further complications and adds to the expense. In dealing with steel cores, which it is necessary to do in a process for the production of finished parts, undercuts or recesses in the casting should be avoided as far as possible. In many cases, of course, collapsible cores may be employed, but this again is apt to lead to further difficulties, to say nothing of increasing the cost of both the die and the finished casting. A slight amount of draught is desirable in many parts, but it is not absolutely necessary.

In order to give strength to certain parts, pins, rings, and bushes made from brass, bronze, or steel may be inserted in the casting. When hard metal is used, the walls of the casting should be at least $\frac{1}{16}$in. thick, but if softer metals are used, they can be somewhat thinner. Although parts as heavy as 5lbs. or 6lbs. may be die-cast, the best results are obtained with those weighing under 3lbs. The fact that they can be made so thin should appeal to designers of such parts as float chambers, carburetter and petrol filters, &c. These, by existing methods, are sometimes made heavier than necessary because of the difficulties of casting and machining.

The ideal design for a part, therefore, is one wherein none of these accessories to the die are needed and in which, when the die is opened, the casting is ready to be ejected. In many cases this ideal cannot be realised, but it should be the endeavour of the designer to reach it as near as possible. The result of overlooking this point can best be shown by an example reproduced from the "American Machinist." Fig. 1 shows the design of a bearing submitted for die-casting. The circumferential groove was put in solely to lighten the piece, but the effect was an increase in cost that outweighed the value of the metal saved. In Fig. 1 is shown the die, composed of four parts, which was necessary for the design in question; and Fig. 2 shows a die in two parts as it could and should have been made. Furthermore, as the latter is solid, it would have been much better if extreme accuracy on the outside diameter had been essential.

A feature in die-casting that will appeal to manufacturers is the remarkable degree of accuracy obtainable. So long as the dies are in good condition, the castings should be perfectly true and uniform, both in shape and size. This obviates the necessity for gauging, and renders it possible to use the castings without recourse to handwork fitting. Interchangeability is thus secured with much more certainty than by machining. Cast parts are usually alike, and, being absolutely accurate, the time saved in assembling is considerable. Another important point which should attract manufacturers, is the saving in machining in several ways. Not only is all machine work eliminated, but also the need for machine tools, the workmen necessary to operate them, and the cost of their upkeep. The expense of building jigs and fixtures is also avoided; no cutters, reamers, taps, or drills are required for this branch of production; and in addition, the labour required for operating the casting machines may be classed as unskilled. No matter how intricate or exacting the machine work on each piece may be, or how skilful a workman is required to produce the work when machine made, the same results may be gained by die-casting. Usually the finished article is superior, and, with the exception of the die-making, only unskilled men are required. For repetition work the cost is very much lower than that of existing methods, and the more complicated the piece, the greater the economy. In the case of apparatus which is now made in several parts because of the need for machine finishing them, these parts can generally be combined into one casting, thus considerably cheapening the work and giving it a much neater appearance. A further considerable saving may be effected in overhead charges by using a hand-operated machine, as no power is then required. After the dies are made, the only thing required is gas for melting the metal, and then the castings can be turned out by the thousand. Many parts which it has hitherto been impossible to manufacture satisfactorily, owing to machining difficulties, can be made by this process. Inventions which otherwise would have to be shelved as impracticable, or too costly owing for instance to the limits of accuracy required being too close to be commercially practicable become marketable. This has already been proved in the case of several inventions outside the automobile industry.

The strength of die-castings is, of course, largely dependent on the nature of the alloy, and also the methods of casting. Unless precautions are taken to ensure soundness, much trouble may be encountered from blow-holes, the causes of which I will enumerate later. Exact figures as to the strength of die-castings would be quite misleading unless the exact composition and treatment of the castings were also noted, so that general figures only can be given. They compare very favourably with cast iron in tensile strength, but not in compressive strength, which latter is usually very little greater than, say, one-third of the tensile strength. As the material is not so brittle as cast iron, it can withstand shocks which cast iron would not. Most die-castings are much more ductile than cast iron, and this greater ductility is an advantage for threaded and tapped work. The castings do not chip out when tapped close to the edge, and a fine thread may therefore be used.

For die-casting many different alloys are compounded. They must be of fine close grain, free from porosity, and low in shrinkage. Castings intended for certain uses must have high tensile strength and great hardness, and these properties can only be obtained at the expense of ductility. On the other hand, castings of high ductility can easily be made, but in this case tensile strength and hardness have to be sacrificed—a general rule which applies to the manufacture and production of alloys and metals for other purposes. The metals that

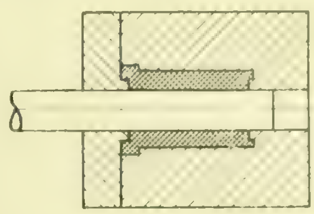


Fig. 2.

produce the best die-castings are alloys of lead, tin, zinc, antimony, aluminium, and copper, and it is from these, according to the best authorities, that most die-castings are made at the present time. So far as my own knowledge goes, no one up to the present has marketed die-castings of yellow metals or has successfully made them on a commercial scale from alloys or metals that have a melting point higher than that of aluminium, that is, about 1,200° Fah. Aluminium in small percentages is used in many die-casting alloys. It acts as a purifier and causes the metal to flow more freely into the die. The reason so little success has yet been achieved with alloys of higher melting point, is that the oxidisation which takes place on the casting surface of the steel die, when the temperature is raised by the molten metal coming in contact with it, causes the mould to change in size and shape, thus destroying the accuracy of the finished work. Furthermore, it is only by producing castings accurate in size and shape, so saving all machining, that the process can be commercially successful. Naturally, this would be a very expensive method of producing castings if they required machining afterwards. Table I gives the analyses, gleaned from various sources, of the castings produced by some of the leading makers.

In the case of No. 5, the sum of the percentages is 100·40. This anomaly is explained by the fact that after melting the other metals the aluminium was added as a deoxidiser. In No. 3, the percentage of iron is an impurity.

While zinc and aluminium in certain proportions, and under special conditions, might make good die-castings, the proportion of aluminium must not be very high, or the piece will show a tendency to disintegrate. An alloy composed of 50 per cent. zinc and 50 per cent. aluminium, according to some authorities, would disintegrate into a granular mass in one year. Such a mixture, even though possessing considerable strength at the time of casting, would very soon lose it and crumble up. As a matter of fact, some of the die-castings now made do disintegrate and therefore their strength becomes greatly impaired in the course of two or three years. This,

however, is entirely due to improper mixing of the constituent metals in the alloy, and there should be no difficulty in preparing it in such a way that there will be practically no disintegration. Zinc and tin mixtures also show an inclination to disintegrate, hence some other material has to be mixed with them as a binder. They are also inclined to be brittle unless copper is added, which has the advantage in addition of making them good for wearing parts. Antimony and bismuth have been frequently used in combination with lead to give it a greater hardness, and where no great strength is required, such an alloy may be used.

Table I.—*Composition of Metals used for Die Castings.*

No.	Zn	Sn	Cu	Al	Sb	Pb	Fe	Description.
1	73·8	14·7	5·3	6·2	—	—	—	No great strength required.
2	72·7	19·0	5·0	1·0	0·3	2·0	—	
3	73·8	12·0	10·6	3·4	—	—	0·2	Slightly harder than Nos. 1 and 2.
4	46·2	30·8	20·4	2·6	—	—	—	Very hard castings.
5	93·0	3·5	2·0	0·4	1·5	—	—	High zinc base alloys.
6	90·0	1·0	6·0	3·0	—	—	—	
7	83·0	5·0	10·0	2·0	—	—	—	
8	90·0	1·0	6·0	3·0	—	—	—	
9	85·0	5·0	5·0	—	5·0	—	—	
10	87·0	10·0	3·0	—	—	—	—	Shonberg's patented alloy.
11	—	4·0	1·0	—	15·0	80·0	—	Lead base alloy.
12	—	87·9	8·5	—	3·6	—	—	Bearing alloy.
13	—	90·6	7·5	—	1·9	—	—	
14	—	60·0 to 90·0	2·0 to 10·0	—	Small Percentage.	—	—	Tin base—Carburetter parts.

It may now be advisable to say a few words concerning bearing metals. Some very exhaustive experimental tests upon white metal, or anti-friction alloys, have been made by the Royal Italian Navy (which are given in the Proceedings of the International Association for Testing Material, 1912). It was proved that, in order to get good results from anti-friction alloys, not only must the greatest care be exercised in compounding and preparing the constituent metals, but no less care is necessary in determining the temperature at which they are fused before being encased. The following are the deductions taken from the results of the above-mentioned tests: (*a*) The temperature of fusion exercised a notable influence upon the capacity of the alloy to diminish friction. (*b*) For each alloy there is probably a fusing temperature which should be applied in order to secure the best practical results.

These statements sufficiently prove that importance must be attached to the use of reliable pyrometers when pouring white metal into the bearing, for the purpose of ensuring that the metal is fused at the correct temperature. This emphasizes the importance of maintaining a constant and correct temperature when die-casting bearings.

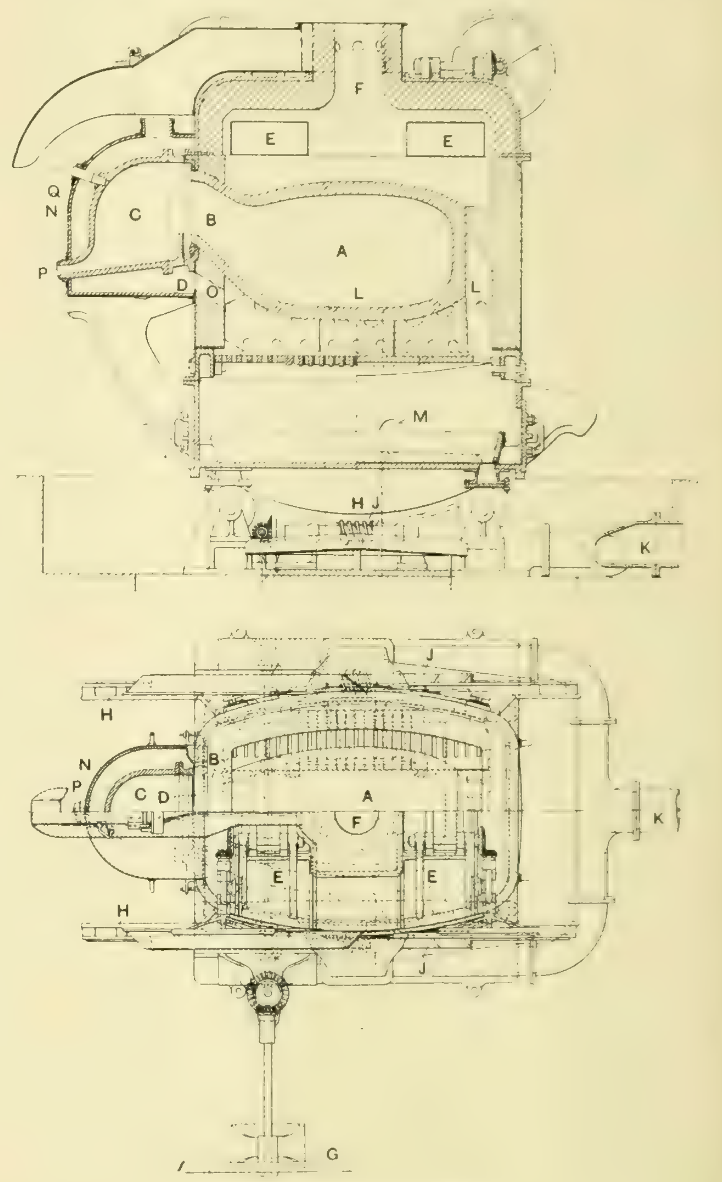
Another great difficulty encountered in making die-castings is their liability to be porous, or full of blow-holes at a place where it is least desirable. Blow-holes result from one or more of the following causes: (1) Air confined in the mould or die when the metal is forced into it. (2) The form of the casting. (3) The tendency of the metal to hold minute bubbles of air, or other gases, which are carried into the die, and do not escape before the casting sets.

In order to overcome the trouble of air in the die itself, the general practice has been to exhaust the air as much as possible from the die just previous to letting in the molten metal; but the vacuum created in the die has been found to cause some of the metal to spray up into the die from the melting pot, and this metal, when cool, more or less sealed up the air vents in the die. Thus, when the metal was forced in, there was air in the mould which had no means of escape; or, if there was an opening, it was too small to let out the air fast enough, and blow-holes inevitably occurred. In fact, considering the speed at which the metal for casting is forced in, an opening almost as large as the gate itself would be needed to let the air escape fast enough to avoid blow-holes. In this event, no vacuum of any description could be obtained. In order to overcome this difficulty, Mr. C. M. Grey, of the C. M. Grey Manufacturing Company, of New Jersey, invented a machine some time ago in which a double vacuum is used, that is, a vacuum in the die and another at the back of the metal. I will give a description of this machine a little later on.

(To be continued.)

CRUCIBLE FURNACE FOR METALS.

The accompanying illustrations show a construction of furnace chiefly designed for metallurgical operations, wherein volatilisation of the metals under treatment takes place, such volatilised metals or gases, driven off from the metals or substances treated being condensed and collected. Heretofore it has been usual to employ either one or several crucibles, arranged separately or together in melting chambers of the fixed or tilting description, and before or when the fumes begin to come off, to arrange covers over the open vessels, so as to make them into retorts, and to connect the vessels by a conduit to a condenser placed by the furnace; also it has been proposed to make use of a bottle-shaped retort in a furnace mounted upon trunnions In either case, however, the joints between the connecting device and the retort, or between the crucible with its cover, and the condenser have to be luted to



Crucible Furnace for Metals

render them gas tight, which operation is attended with considerable difficulty and uncertainty, as the luting of the joints has to be effected on hot surfaces.

In the furnace under notice, the invention of the Morgan Crucible Company, Ltd., of Battersea Works, Battersea, London, H. Davison, and L. C. Harvey, there is arranged between the retort or crucible and the condenser an intermediate piece through which the fumes pass and which at one end is permanently luted to the retort and at the other end provided with a surface against which the condenser will directly joint, without the necessity for the luting of the joint. Referring to the illustrations, A indicates the retort or crucible, so arranged that the opening B for the charging and discharging of the retort is at one end of the latter in the usual

way, and C is the condenser which constitutes a kind of hood and which is designed to joint against the intermediate piece D which is in the form of a ring permanently luted to the mouth of the retort, so that the operation of luting or pugging the joint around the condenser each time the latter is applied is rendered unnecessary. In practice the retort is mounted in a melting chamber of metal construction having a brick lining and made in two sections to allow for the introduction or renewal of the retort. The upper part of the melting chamber is provided with a flue opening F for the escape of the products of combustion from the furnace, and with openings E which serve for charging fuel into the furnace and for affording access to the interior of the chamber. The lower part of the melting chamber contains the grate on which the retort is suitably supported. Below the melting chamber is formed an ash pit, in the bottom of which a tray is placed for collecting the contents of the retort should the latter crack or become broken. The furnace is provided at the lower part with rockers H mounted upon bearing rollers and attached to or formed integral with these rockers are toothed quadrants J, with which worms controlled by gearing and operated by a hand wheel G engage in such a manner that the melting chamber and ash pit with the retort can be rocked to tilt the latter, either to discharge the contents of the retort, or to incline or place the retort with its mouth uppermost so that it can be quickly charged; also, by this means the level of the molten charge can be maintained at any desired point during the melting process, or when the volatilisation and distillation of the metals or substances takes place.

The air supply of the furnace is provided for by arranging, in conjunction with an air supply pipe K, air boxes which bear against the external surface of the ash pit, and are connected with the latter through holes M formed therein. These air boxes are elongated or made of such dimensions and shape that the openings in the ash pit will remain in communication with them notwithstanding the backward tilting of the furnace when placed so that the mouth of the retort is inclined upwards for charging or other purposes. A series of tuyere holes L is also formed round the furnace through which holes air from below the grate passes through ducts and controlled by dampers to the melting chamber. The condenser C is hinged to the metal casing of the melting chamber, so that it can be readily swung into position over the mouth of the retort A and removed therefrom when required, the condenser being adapted to joint against the intermediate piece or ring D and to be fixed by a pin. Around the condenser C a metal shield N, lined with a non-conductor of heat, is arranged and fixed in position by nuts and bolts, so that it can be easily removed, this shield also extending over an opening O in the wall of the melting chamber, through which the gases from the furnace can pass into the space between the shield and condenser, so as to warm the latter, an opening being formed at the top of the shield for the escape of the gases into a flue which communicates by openings with the flue opening F. The condenser is also provided with a tap hole P for discharging from time to time the materials that may accumulate therein, and is so constructed that, if necessary, a bath of the condensed metal or substance can be maintained therein to assist the rate of distillation. The shield and condenser are provided with a sight hole Q normally closed by a plug.

For such processes as do not necessitate the removal of slags after the completion of each heat, and where a continuous process is desirable, the retort A can be provided with an additional mouth or opening in any desired position and the furnace so arranged that it is possible to leave the condenser described fixed in position and undisturbed, this second opening serving as the charging and pouring aperture, which can be closed by a plug, stopper, second condenser box, or similarly arranged air-tight door when charging is complete and volatilisation is to take place. Although the furnace described is particularly adapted for coke or other solid fuel, it can be equally well constructed for liquid or gaseous fuel.

Manchester and the British Association.—At the meeting of the British Association in Birmingham in September next an invitation will be submitted to the association to hold its annual meeting at Manchester in 1915. The Lord Mayor (Mr. S. W. Royse) will be the bearer of the invitation.

ROLLING-MILL PRACTICE IN THE UNITED STATES.*

BY J. PUPPE, D.ENG.

(Concluded from page 560.)

PLATE ROLLING-MILLS (Table V.).

For rolling heavy plates, 3-high mills, especially of the Lauth type, are more often used in the United States than any other type, whereas both in Germany and England the reversing 2-high mill is preferred, especially for thicker plates, and when the length of roll exceeds 6ft. 6in. It is difficult to account for the origin of the use of trios, with their heavy lifting tables and complicated gear, and the reason can hardly be sought in the simpler method of driving, considering that the steam reversing engine has reached a stage of high perfection, and that electric driving is also available. Moreover, in the case of universal rolling mills the reversing duo type predominates. In the matter of output the two types of mill are also about equal, and the only reason to account for the retention of the trio is that it has long been a favourite type in America.

A departure from the ordinary kind of construction of a 3-high plate mill is exhibited in the heavy plate mill of the Carnegie Steel Company, an example of which is probably not to be found in Europe. In this mill the middle roll is stationary and the upper and lower rolls are alternately raised and lowered. At the works of the Illinois Steel Company are two trio stands working in connection with each other, the second of which has rolls of a larger diameter, on account of the necessary acceleration during the rolling process. This arrangement of two stands for roughing and finishing increases

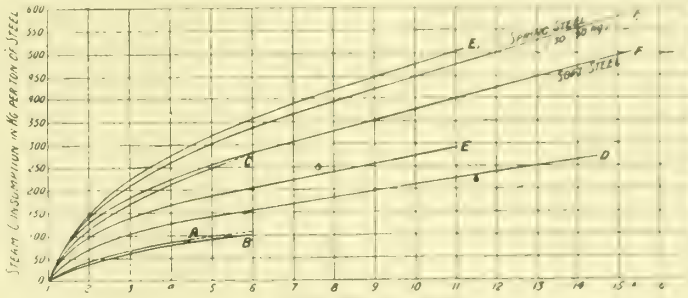


FIG. 3.—STEAM CONSUMPTION OF COGGING MILL ENGINES. (See Table VIII.)

the capacity of the mills and also improves the appearance of the plates, since the work of rolling is distributed between the two stands in such a manner that the finishing rolls are subjected to less wear and tear than the rolls of the first stand. This method of work and arrangement has lately been increasingly adopted in England for structural and ship plates, the usual arrangement being to place the two stands one behind the other, with the object of saving as much space as possible. The roll diameters are often remarkably small compared with those usual in European practice. For a roll length of 10ft. 8in., German practice would require a diameter of at least 39in., and probably one of 43¼in. would be considered desirable, whereas in America 34¼in. is considered sufficient. It would appear, therefore, that the risk of breakdown does not weigh so much as the ability to work with a less power consumption and obtain to a higher production, a necessary condition being, of course, that the ingots or slabs should be well and uniformly heated, a matter which presents no difficulty in view of the unlimited supply of cheap fuel.

SHEET MILLS (Table VI.).

One of the most recent industries of the United States is the sheet and tinplate industry, which owes its rise largely to the increased protective tariff introduced in 1891 and to the enormous demand for tinplate in the country. Prior to that date the high price of raw materials, high wages, and inability to dispense with manual labour in the manufacture of tinplate had presented great obstacles to the establishment of a home industry; but after 1891 tinplate mills rapidly sprang up in many places, an additional impetus being given by a lowering of the price of raw materials, due to a depression in

* Paper presented at the annual meeting of the Iron and Steel Institute, May, 1913.

the iron trade about that period and a simultaneous fall in wages. Some idea of the growth of the industry can be gathered from the statistics of production, which show that the quantity of tinplate manufactured in America increased from 999 tons in 1891 to 74,260 tons in 1894, and thenceforward rose steadily to 712,147 tons in 1911.

Table V.—*Plate Mills.*

No.	Name of Company and Place.	Type.	Particulars of Drive.					Rolls.		Yearly Output (Tons).
			Type.	Dimensions (mm.).	Revolutions.	Steam Pressure.	Capacity (h.p.).	Diameter (mm.).	Length (mm.).	
1	Carnegie Steel Company (Homestead)	Trio 1st stand (Lauth)	Tandem compound direct coupled	813/1270 × 1524	85	144lbs.	1300	762	1840	45,000
2	Carnegie Steel Company (Homestead)	Trio 1st stand (Lauth)	Tandem compound	889/1372 × 1524	—	144lbs	2550	—	2140	100,000
3	Carnegie Steel Company (Homestead)	Trio (Lauth)	Flywheel steam-engine direct coupled	1168 × 1524	78	130lbs.	2000	864 middle roll 533	3250	170,000
4	Carnegie Steel Company (Homestead)	Trio with rolls of equal diameter	Tandem compound direct coupled	1067/1676 × 1524	—	144lbs.	3000	965	3560	178,000
5	Illinois Steel Company......	Trio 1st stand (Lauth) Trio 2nd stand (Lauth)	Flywheel steam-engine for both stands	1370 × 1925	60	—	—	863 (460) 915 (530)	2300 3350	135,000

The construction of sheet mills and rolling practice differ very little from current practice in Germany, except that the stands of the mills are set very wide apart, necessitating long driving shafts. An attempt has been made to introduce continuous mills, with the object of manufacturing on a large scale and dispensing with manual labour. A sheet mill on the Bray system was installed in 1906 by the American Sheet and Tinplate Company at South Sharon, but this is not a continuous mill in the true sense of the term, as a plate is never being rolled in two or more stands at the same time. Moreover, the plates, after rolling down in nine successive stands, are finished in sheet mills of the ordinary type.

Table VI.—*Sheet Mills.*

No.	Name of Company and Place.	Number of Stands.			Particulars of Drive.					Number of Stands driven by an Engine.	Rolls.	
		Roughing.	Hot rolls.	Cold rolls.	Type.	No.	Dimensions (mm.).	Revolutions.	Capacity (h.p.).		Diameter (mm.).	Length of Roll.
1	Jones & Laughlin Steel Co. Hot rolling mill	—	24	—	Tandem compound	2	860/1524 × 1524	28	3000	12	710	760–915
2	Jones & Laughlin Steel Co. Cold rolling mill	—	—	18	Flywheel compound	1	762/1524 × 1524	40 41 42	768	18	610	815–915
3	American Sheet and Tinplate Co. (Vandergrift)	16	24	8	Flywheel steam-engine with counter shaft	3	—	75	1600 each	2 engines each driving 20 stands, 1 engine driving 8 stands	Hot rolls 610 Cold rolls 610–660	1016–1420 965–1420
4	Youngstown Sheet and Tube Co., New mill	4	8	4	Tandem compound	1	915/1630 × 1524	30	2000	16	—	Hot rolls 865–1425 Cold rolls 1015–1425
5	Youngstown Sheet and Tube Co., Old mill	3	6	3	Tandem compound smaller engine.	1 1	330/365 × 915	—	—			1016–1425

Strip Mills (Table VII.)

Tube strip is the intermediate product in the manufacture of welded tubes, and the strips in some respects resemble flat bars. But as they are thinner, and as much greater accuracy in width is required, the method of rolling differs. The stands of the continuous mills are not all arranged behind one another at regular intervals, but are set in groups which are driven separately for the most part. The grouping is not uniform, but differs in different mills. By dividing a mill into separate groups in this way, a uniform width can be more accurately kept, it being impossible to use guides here, as is done in the bar mills, on account of the much higher speed of rolling, which is about twice that used in rolling bars. One of the final stands is provided with a pair of vertical rolls, which are intended to remove any inequalities in width; in one instance these vertical rolls were placed in front of the first stand, with the idea of removing any unevenness in the section of the billet at the start. The arrangement of

the strip mill of the American Steel and Wire Company at Cuyahoga consisted of six continuous stands as a roughing train, following which were three double duo stands. In these the bar is automatically guided from the lower to the upper pair of rolls. In the last three finishing stands a limited adjustment of the rolls is possible for strips of different thicknesses, and a pair of vertical rolls is combined with one of the stands.

The roll diameter is very small in proportion to the large width and thinness of the strips, and does not admit of any great length of roll body; also, since the strips cannot conveniently be rolled in smooth or stepped rolls, the rolls must be grooved, and it is not possible to have many grooves in so short a length of roll body. In Germany tube strips are not yet rolled in continuous mills, though as a special product in large demand there is no reason why they should not.

The rolling operation is very rapid. At the National Tube Company's mill, strips 7in. by $\frac{3}{16}$in. were rolled and finished from 4in. by 6in. billets in nine passes through the nine stands in 38 secs. The average reduction per pass is 27 per cent., which is to some extent facilitated by corrugating the bottom of the first few grooves

To save planing the edges of strips intended for lap welding, the last roll is so grooved that strips with bevelled edges are obtained, thus avoiding the necessity of further machining. Only in the case of strips for tubes over 14in. diam. are the edges bevelled on the planing machine, everything below that size being bevelled in the mill. The proportion of rejections of such strip is, however, fairly high, the loss of material between the ingot and the finished tube being 12 to 13 per cent.

Method of Driving.

In general, in the United States the steam engine has until lately been preferred for supplying the motive power to rolling mills, and at the present day the majority of mills are still driven by steam. Lately, however, electricity, which has long been used for driving the auxiliary machinery, has made great headway as an agent for driving the mills themselves. It has not yet been attempted to drive the mills with gas engines, whereas in Germany gas engines are already in use in many cases with considerable success. In the American works inspected it was noticeable that mills of different size and of various capacities were driven by steam engines of equal power, the reason being that, owing to the demand for quick delivery, engines of a standard size and type can be supplied at shorter notice than is the case when designing an engine to meet particular requirements.

From trials for determining the power requirements, it was found that the steam consumption in non-condensing engines averaged 270 kg., and in condensing engines about 180 kg. per ton of material rolled to eight times the original length (see diagram, Fig. 3). In Table VIII. the steam consumption of engines in American mills is given.

Electric driving for rolling mills was comparatively late in being adopted in the United States, although electric auxiliary machinery was first used in American ironworks. As soon as the success of the first installations had been fairly proved, the change to electric driving proceeded rapidly and with characteristic energy. By the end of 1911, about 52 electric motors for driving rolling mills had altogether been built and installed. At the new Gary Works electric driving was adopted throughout, and the simplicity of the mill arrangement facilitated its introduction.

In general, alternating current is used for driving the larger motors and direct current for the smaller auxiliary motors. The direct-current motors receive their supplies from a motor generator driven by an alternating-current motor supplied from the central power station. Where two speeds are required in rolling, as in the Gary universal mill, a direct coupled alternating-current induction motor with commutating poles is used, the commutation being effected by an auxiliary motor without interruption of the current. By this means it is possible in a total of 19 passes to double the speed between the 9th and the 10th pass, and to drop again to the original speed between the 19th and the 1st pass. The speed variation is from 40 to 80 revs. per minute, but no data are available as to the durability of this arrangement.

Table VII.—*Strip Mills.*

No.	Name of Company and Place.	Type.	No. of Stands.	Particulars of Drive.					Roll Diam. (mm.)	Class of Material Rolled.	Initial Section (mm.).	Production.
				Type of Engine.	No. of Engines.	Dimensions (mm.).	Revolutions.	Capacity (h.p.).				
1	National Tube Co.	Continuous	5 4 + 1 finishing	Flywheel steam-engine	1 1	—	—	— —	330	Tube strip 152–355 mm. wide	102 160	—
2	National Tube Co.	Continuous	6 4	Flywheel steam-engine	1 1	—	— —	2400 800	305	Up to 300 mm. wide	—	570 tons in 12 hours
3	National Tube Co. (Lorain)	Continuous	11 (stand 2 with vertical rolls) 3	A.C. motors 6600 volts 25 cycles	1 1	— —	187·5	2500	406	-	—	—
4	American Steel and Wire Co. (Cuyahoga)	Half continuous	6 duo continuous 3 trio 1 duo finishing	A.C. induction motor 2080 volts	1	—	214	1800	—	Hoop-iron 63–178 mm. wide by 1·19 thick	102–160	90 tons in 10 hours (average kilowatt consumption per hour, 700 800)
			2 } duo 1 } finishing	Flywheel transformer with D.C. motors 575 volts	1 1	A.C. induction motor 1400 h.p. 2080 volts, and D.C. dynamo 1000 kilowatts, 10 poles	210 315 290 360	800 800	— —			
5	Youngstown Sheet and Tube Co.	Continuous	6 4	Flywheel steam-engine	1 1	—	— —	—	254	Tube strip up to 125 mm. wide	—	—
6	Youngstown Sheet and Tube Co.	Half continuous	1 trio roughing stand with 2 vertical rolls, 3 continuous	Tandem compound direct coupled Tandem compound geared	1 1	510 1016 × 1220 510 1016 × 840	— —	— —	510 410	—	—	—

The principal dimensions and weights of the parts of this motor are as follows:—

Rotor (20ft. 2in. diam.),	weight about	95 tons
Stator	,, ,,	79 ,,
Shaft	,, ,,	23 ,,
Bearing supports ...	,, ,,	63 ,,
Bed plate (32ft. 9in. by 21ft.) ,,	,,	84 ,,

The motors are almost exclusively alternating-current slip-ring motors; in a few instances they are arranged in cascade or with commutating poles or with short-circuit rotors. Short-circuit motors with additional rotor resistance are used for the finishing stands of the strip mill at Cuyahoga, and are supplied from generators driven by three steam turbines. The consumption of power is said to amount to 50 kw.-hours per ton, though these figures do not appear to be very trustworthy. The average consumption per hour is given as 700 kw. to 800 kw.

The size of the alternating-current motors is 20 per cent. larger than that of the corresponding direct-current motors, and latterly they have been so constructed that the stator can be moved sideways along the main shaft so as to clear the rotor for repairs.

The turbine is intended to work with live steam at 145lbs. pressure or exhaust steam at 16lbs. pressure. It may be assumed that exhaust-steam turbines for the generation of electric energy have not found any greater favour in the United States than in Germany, and that results are being awaited before they are likely to become more widely adopted, especially as an adjunct to rolling-mill engines. On account of the intermittent load the amount of waste steam fluctuates considerably, so that the output of the exhaust steam turbine can only be constantly maintained by using live steam, and it is questionable whether the economy of such an installation is greater than an ordinary condensing plant. Where, however, an exhaust turbine is connected to several rolling-mill engines, especially to the non-reversing flywheel engines driving 3-high mills, as at the works of the Illinois Steel Company and at the Tennessee Coal, Iron, and Railroad Company, some economy might be achieved on account of the considerably lower consumption of live steam.

Since the end of 1910 the new plate-rolling mill of the Calderbank Steelworks has been driven direct with a mixed steam turbine. This method of driving direct with a turbine was adopted after careful trials and calculations, which showed

TABLE VIII.—*Tests of Steam Consumption in Cogging-mill Engines.*

	Place and size of mill.	Type of engine.	Dimensions (inches).	Size of ingot.	No. of passes	Final section.	No. of times by which piece is lengthened	Curve of diagram (Fig. 3).	Remarks.	Steam consumption per ton. Of material rolled till length as given in column 7.	Steam consumption per ton. In terms of rolling to 8 times original length.	Steam consumption per h.p. hour.
Trio Mills.	40in. Bessemer ..	Allis-Chalmers tandem compound condensing	50/78 × 60	Head $17\frac{3}{4} \times 18\frac{1}{2}$in. Base $18\frac{1}{2} \times 19\frac{3}{4}$in. Length 5ft. 3in.	7	91 · $9\frac{1}{4}$in. 21ft. long	4	A	Condensing	82·5 kg.	130 kg.	—
	43in. Youngstown	Allis-Chalmers tandem compound condensing	52/90 × 60	Head $17\frac{3}{4} \times 19\frac{3}{4}$in. Base $19\frac{3}{4} \times 21\frac{1}{2}$in. Length 4ft.	9	8 × 8in. 24ft. long	6	B	Condensing	104	120	—
Reversing Mills.	38in. Duquesne ..	MacIntosh-Hemphill twin reversing engine	42 × 60	Head $17\frac{1}{4} \times 20$in. Base $18\frac{1}{2} \times 21\frac{1}{2}$in. Length 5ft. 9in.	13	$8\frac{1}{2} \times 7\frac{1}{4}$in. 32ft. 9in. long	5·7	C	Non-condensing	270	330	23·9 kg.
	36in. SouthSharon	Allis-Chalmers twin tandem compound	42/70 × 54	Head $17\frac{3}{4} \times 19\frac{1}{2}$in. Base $20\frac{1}{4} \times 22\frac{1}{4}$in. Length 5ft. 4in.	19 21	$7\frac{1}{2} \times 3$in. 82ft. 2in. long $5\frac{1}{8} \times 5\frac{1}{8}$in. 79ft. 6in. long	15·5 15	D	Condensing	280	180	—
	40in. Aliquippa ..	MacIntosh-Hemphill twin tandem compound	44/70 × 60	Head $19\frac{3}{4} \times 21\frac{1}{2}$in. Base $21\frac{1}{2} \times 23$in. Length 5ft. 2in.	25	$6\frac{1}{2} \times 6\frac{1}{2}$in. 59ft. 4in. long	11·5	E E_1	Condensing Non-condensing	300 520	270 420	— —
	40in. Duquesne ..	MacIntosh Hemphill twin tandem compound	40/70 × 60	Head $17\frac{1}{4} \times 20$in. Base $18\frac{1}{2} \times 21\frac{1}{2}$in. Length 5ft. 9in.	19 25	6 × 4in. } 86ft. 3in. 6 × 4in.	15 15 (springmill)	F F_1	Condensing Non-condensing	490 580	325 390	— 22·3 kg.

In some cases the waste steam of rolling-mill engines is used for driving turbines for the generation of electric energy. At the Illinois Steel Company's works a turbine using both live and waste steam has lately been installed. It is supplied with waste steam from two reversing and two twin tandem engines. When driven with waste steam alone it develops 3,000 kw., and with live steam 4,000 kw.

At the works of the American Sheet and Tinplate Company, the cogging-mill engine has attached to it a mixed steam turbine with a Rateau generator. The turbine is coupled direct to an 8-pole 1,500 h.p. direct-current dynamo of 250 volts, and with an output of 500 kw. it uses less than 18 kg. of steam per kilowatt-hour at atmospheric pressure.

A Curtis exhaust steam turbine at the works of the National Tube Company, which was attached to the engine of the 36in. reversing 2-high cogging rolls, drove a 3,000 kw. dynamo generating alternating current at 6,600 volts, 35 cycles, running at 1,500 revs. per minute, but it burst in consequence of the high speed and the failure of the valve. Another Curtis mixed-steam turbine of 7,000 kw. capacity, connected to rolling-mill engines, was lately installed at the works of the Tennessee Coal, Iron, and Railroad Company.

that a $13\frac{1}{2}$ per cent. higher efficiency would be gained by direct driving than by interpolating an electric dynamo and motor. The anticipated results have been fully realised, and it appears that a turbine is well adapted for driving rolling mills, on account of its comparatively high capacity for overloading. In the case of mixed steam turbines, however, the question of regulating presents some difficulties, which at Calderbank Steelworks have been overcome by using a heavy flywheel, which lessens the effect of the fluctuations in the load. This method of driving is likely to find adoption in Europe, especially in view of the economy in first cost by dispensing with the electric engines. The necessary train of gear wheels between the turbine and the rolls would present no technical difficulties at the present day.

Reviewing the rolling-mill practice in America, and the peculiar characteristics of construction and arrangement which have been made with a view to obtaining the greatest possible output, it is unquestionable that the results aimed at have been fully achieved and must command the admiration of all practical iron manufacturers. But the creation of an iron industry on such a scale as that which has been achieved by the skill and foresight of the Americans is only possible given

certain economic conditions. The organisation necessary to enable manual labour to be dispensed with must be thorough and complete, and is dependent upon the condition of being able to manufacture on a large scale. This again is only possible where the market conditions are favourable. It is clear that special mills cannot be worked at a profit unless they can be run at their full capacity, as the experience of the past two or three years has shown, in the case of the Gary rail mill. In comparing German practice with American, and taking into consideration the difference in the economic conditions in the two countries, there is no reason to be dissatisfied with the present state of development of rolling mill practice in Germany.

The only feature which might, with advantage, be adopted in Europe is the continuous rolling mill, either in the form of the entirely continuous mill or of the continuous roughing mill. The entirely continuous mill can only be used for the same purpose as in America, that is, for rolling a very limited class of goods, such as billets, bars, wire rod, or tube strip. They would therefore be special mills, and their profitable use would be governed entirely by the market conditions and purposes for which the finished product was required. Such mills are quite suitable for German conditions, and some are already in operation, but they are quite impracticable for small sections which may be required in many shapes.

The economy of continuous mills as roughing trains for small and medium-sized sections depends upon market conditions only, that is, upon the class of goods rolled. This explains why certain mills built here in accordance with American practice have failed to fulfil the expectations of their builders, until the class of goods rolled was strictly limited to a few sections most in demand, thereby avoiding the frequent changing of rolls. Even then the advantages are only apparent, as the other trains become overloaded with the sections which the continuous roughing train cannot take.

From what has been said, it is apparent that it would be out of the question to adapt American systems of rolling mills and rolling methods to European conditions, notwithstanding, of course, that many valuable object lessons may be learned from them. The lowering of the cost of production by allotting orders for certain classes of product to certain mills is a great advantage, since, under these circumstances, a whole works can be equipped for one or two particular classes of product. The founding of the United States Steel Corporation greatly facilitated this subdivision of rolling-mill work, and it would undoubtedly be of great advantage to copy this practice in Europe.

In conclusion, the author has to express his most cordial thanks for the kind reception accorded to him and his friends everywhere in the United States. The utmost readiness was displayed in permitting him to visit and inspect the works, and all kinds of information and data were unreservedly placed at his disposal. The unfailing courtesy and kindness which he met with on the part of all concerned demand the author's grateful acknowledgment.

AIR AS A STIMULATOR OF CORROSION IN REFRIGERATING SYSTEMS.

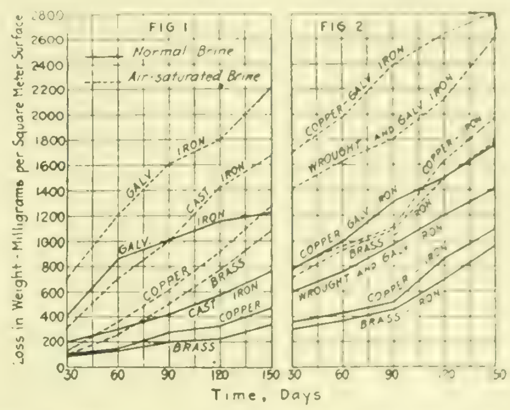
IN our issue of February 28th last (see page 223 ante) we reproduced from our American contemporary "Engineering News" an interesting article by Mr. F. N. Speller on "The Design of Hot-water Supply Systems to Minimise Corrosion," in which attention was directed to the influence which dissolved gases (oxygen and carbonic acid) in water have on the corrosion of hot-water supply systems, and suggestions made for rendering the water practically harmless by removing as much of the air as possible after heating.

Mr. M. B. Smith, in the following article from the same journal, states that the suggestions contained in Mr. Speller's paper are equally applicable to the design of refrigerating systems, especially to those parts of the apparatus which contain or transmit brine or ammonia, in either gaseous or liquid form.

As early as 1905 the danger due to the acceleration of corrosion by the action of air, either entrained as gaseous particles or in solution in the brine, was pointed out by the writer after a very thorough investigation of a severe case of corrosion throughout the refrigerating system in one of the large office buildings at Pittsburg. The system in this building furnished refrigeration to a cafe on the ground floor, to a restaurant and to a club on the top floor, 27 storeys above ground. There was also cold drinking water running on every floor.

All of this large system was more or less affected by corrosion, the corrosion appearing almost without exception at fittings, valves, and pumps. The corrosion was more or less localised at these places and always appeared within the piping or fittings and at the top. All conditions, excepting only the electrical differences of potential found on measurement, pointed to the presence of air either entrained in the apparatus or in solution in the brine itself. Experiments were then started to determine whether or not air was entrained in the apparatus, the first step being to locate the highest point of the apparatus. This being done, holes were drilled through the piping and pet cocks were placed at these points. When the drills broke through the piping there was invariably a rush of air from within. It was proven beyond a doubt that the apparatus had never since its installation been filled completely with brine. The system then was filled completely with brine after placing pet cocks at all points throughout the entire refrigerating system. These cocks were then closed, but remained in readiness to vent the apparatus periodically, and to make it possible thoroughly to fill the brine carrying part of the installation.

It is a very significant fact that the worst corrosion by far was manifest at the very topmost part of the system, showing that air, when entrained as such, works along to high points and that it is perfectly feasible to vent such apparatus and



RESULTS OF CORROSION TESTS OF SINGLE AND TWO-METAL TEST PIECES IN ORDINARY AND AIR-SATURATED BRINE.

prevent accelerated corrosion at such places. In this case there is absolutely no doubt that corrosion was greatly diminished by remedying this fault.

There was still another phase of this question of air in this particular system, namely, that held in solution in the brine. Examination of the brine-carrying parts, especially the return-brine lines, showed that there was an excellent opportunity afforded for the liquid to become thoroughly saturated with air. The brine returning to the main supply tank in the lowest basement fell through air a distance of some 5ft. to 6ft., churning up the brine in the tank and being itself more or less sprayed during its fall. Examination of the brine showed that it carried an abnormal content of dissolved air and showed plainly that something must be done at once to minimise this absorption. Accordingly the return pipe was lengthened so that the brine discharged about 8in. below the surface of the liquid in the tank. This did not put sufficient back pressure on the system to be noticed at all in the operation. Examination of the brine after some weeks of operation showed a content of air not over a tenth of that before making the above change in the piping. The thought came at once that experiments along this line should develop data of value as confirmatory evidence of the facts noted in practice.

Experiments were started in which single metals and combinations of dissimilar metals were partially immersed (⅔ only) in a commercial brine, consisting of calcium chloride, of a strength equivalent to 1·2 specific gravity. The temperature of the tests was from 20° to 25° (room temperature). The duration of the tests was 150 days, sufficiently long to establish the general behaviour of the metals. One set of test pieces were placed in normal brine, the second set being placed in the same brine after saturating it with air.

The writer believes that the results are typical for the conditions maintained; he realises that such results are purely comparative, not absolute, for a change in the metals used would undoubtedly alter the results, and other factors are to be considered, such as auto-electrolysis, &c., which would have their effect in experiments of this sort. The fact is established, however, that air-saturated brine is relatively much more corrosive than brine carrying only a normal amount of air in solution. It is, therefore, highly probable that if refrigerating apparatus were designed to remove air from the system, just as far as is practicable, one of the most highly corrosive agents known will have been eliminated and corrosion undoubtedly minimised.

The experiments were carried out with various metals partially immersed in brine. Test pieces were 6in. long, 3in. wide, and ¼in. thick. These were polished smooth at the start before weighing. At certain intervals the test pieces were removed from the brine, rubbed in hot water with a soft brush to remove any easily-loosened oxide and weighed after drying in alcohol. The pieces were only partially immersed, since this simulates a condition always found in practice. It is also more severe than complete immersion would be under identical conditions. The results are tabulated below and plotted in the accompanying diagrams. Losses are expressed in milligrams per square metre of surface immersed.

Results of Experiments on the Action of Brines on Metals.

(Loss in Milligrams per Square Metre.)

Single Metals.

	Normal Brine.					Air-saturated Brine.				
Days.....	30	60	90	120	150	30	60	90	120	150
Copper.........	100	150	280	330	470	130	360	605	905	1270
Iron (cast) ...	200	300	420	575	760	310	700	1000	1420	1680
Brass	80	130	198	230	340	100	260	500	765	1080
Iron (galv.)...	400	860	1000	1150	1220	700	1200	1605	1800	2210

Combinations of Dissimilar Metals.

	Normal Brine.					Air-saturated Brine.				
Days.....	30	60	90	120	150	30	60	90	120	150
Copper...... / Iron.........	360	430	520	860	1090	786	962	1110	1636	1980
Brass ...... / Iron.........	300	365	465	695	960	710	925	1090	1492	1785
Wrght. iron / Galv. iron..	600	760	970	1200	1410	1410	1625	1810	2130	2605
Copper...... / Galv. iron..	780	1000	1310	1500	1760	1700	1980	400	2650	2810

The increased rate of corrosion, due to air-saturation of brine, is marked in both single metals and in combinations of dissimilar metals. The figures for the combinations of dissimilar metals cover the loss of both metals, but it is probable that this was very largely confined to the iron or galvanising (zinc) on account of active local electrolytic action.

In so far as was possible conditions were maintained alike in all experiments excepting only the amount of air in solution in the brine. The widely different results in the case of normal and of air-saturated brine may be laid to the different amounts of air in solution in the brine. The writer is of the opinion that the designers of refrigerating apparatus should make an earnest effort to so design their apparatus that the amount of air entrained in the apparatus or in solution in the brine may be kept at a minimum constantly. In bringing the results of this investigation forward, the writer hopes that the data contained therein may be of practical value to those engaged in the design of operation of refrigerating apparatus.

Launch of the Destroyer "Midge."—The London and Glasgow Engineering and Shipbuilding Company, Govan, launched, on the 22nd inst., the torpedo-boat destroyer "Midge," the second to be launched of three destroyers which are in course of construction by this company for the British Navy. The dimensions of the vessel are: Length between perpendiculars, 260ft.; and breadth, 27ft. She is fitted with Parsons turbines designed to develop 25,000 s.h.p., and has water-tube oil-fired boilers of the Yarrow type, constructed by the builders. The armament will consist of three 4in. guns and two torpedo tubes.

CASE-HARDENING.*

BY DAVID KEACHIE.

THE process of case-hardening is a very old one. It is full of interesting problems, and is now one of the fine arts in engineering practice. For many years the methods employed to case-harden steel were crude and erratic, a good deal of guess work and mysterious manipulation being employed to get results at the best not very consistent, and which often led to difficulties and failures. These difficulties and uncertainties have now been almost removed, and the process can be carried through with a considerable amount of success provided ordinary care is taken.

Carbon and steel capable of combination have a strong kindred relationship to each other, and the process of case-hardening is founded upon this fact. When a piece of mild steel is heated to a certain temperature, in contact with carbon in a certain form, a combination takes place on the surface of the steel whereby the absorption of carbon converts it from a steel of soft character into that of a hard one, the depth of case depending on the size of the article, the temperature of the furnace, the form of carbonaceous material used, and the length of time the process is continued. Afterwards the articles are reheated and quenched in oil or water. This, as the term implies, is case-hardening, and when a piece of carbon steel suitable for case-hardening is prepared for this process we are confronted with the problem of having to produce from it an article composed of two distinct steels, the carbon content of the core being about ·15, and that of the case about ·90. We require this core to be of soft fibrous structure of great strength, and the case to be dead hard, free from soft spots, and capable of resisting successfully the application of a new file or other edge tool.

The carbonising furnace, which may be heated with coal or oil, should be of a type that permits the boxes in which the articles to be carbonised are contained being heated uniformly to a temperature of 1,000° C. and should be capable of maintaining this temperature without forcing. It should be made so that all cold air is excluded from it, so far as the outer atmosphere is concerned, and should be so constructed that neither the fuel or the flame comes in contact with the boxes, the flame impinging on the sides and roof of the muffle so as to raise the temperature by radiation and not by direct contact. The muffle chamber and the flues, also the door, should be lined with firebrick, and, if necessary, the sides of the door should be luted with fireclay to ensure an effectual seal from the atmosphere. A very important detail is the peep hole in the door of the furnace. This hole is usually fitted with a plug or flap, and provides a means for observing the temperature or applying a pyrometer to register the temperature, if it is of the heat radiation type. By means of this hole observations or readings can be taken without the necessity of opening the door. If the heat measuring appliance is of the thermo-couple type, tubes should be provided for inserting the thermo-couple. A furnace constructed on the above lines will give satisfactory carbonising results.

The hardening pots are usually made of cast iron or boiler plate. Cast-iron pots are cheaper, and can be cast with a foot at each corner. Boxes cast with feet allow a free passage between the bottom of the box and the furnace, thus ensuring a more even heating up of the places to be carbonised, but they are not so easily handled, as the feet tend to sink into the bottom of the furnace with the weight of the box, and shorten the life of the furnace bottom. Cast-iron boxes go very much out of shape, and unless made of very suitable metal are liable to crack and distort long before they have fulfilled their mission. The walls of the boxes being thicker than mild steel, it takes longer for the heat to penetrate to the centre of the box. On the whole, cast-iron boxes are considered unsatisfactory, as they do not stand up to rough handling, and generally give out long before they have performed a reasonable amount of work.

Boiler-plate boxes, though more expensive, are in the long run much more economical, and more satisfactory to handle. These boxes are usually made from boiler plate ⅜in. or ½in. thick, the sides and ends turned up at right angles to the base and gas welded in at the four corners. Those boxes can be used over and over again until they are reduced to a mere

* Abstract of paper read before the Scientific Society of the Royal Technical College, Glasgow, November 23rd, 1912.

shell, it only being necessary after each heating to knock off the scale which the previous heating has formed. Owing to their malleable nature they are very much less liable to crack, and seldom fracture under the fairly rough treatment received in the hardening shop. When distortion takes place they can be heated and easily straightened into shape again with a hammer. In practice mild-steel or boiler-plate boxes are found to do the work much more efficiently, and can be recommended in place of cast iron for this purpose.

The sealing of the box is an important point in successful carbonising, and can best be done by a simple mild-steel lid made to fit loosely into the box. The box is packed to allow of the lid coming flush with the sides, so that a luting of clay can be easily applied round the edge to keep the contents air tight. A lid let into the box in this fashion has the advantage of keeping the contents more compact in the process of carbonising, and is better than any sliding or dovetailed joint, which will quickly give trouble owing to the different temperatures to which the boxes are subjected.

At no point in the process are we confronted with so many possibilities as in the selection of a suitable carbonaceous mixture. The best carbonisers in general use to-day are bones, good charred leather, or other simple form of animal charcoal. Many people make up mixtures for themselves, but the best results can perhaps be obtained if the mixture is purchased from a firm of repute who have made a special study of the subject, and who produce a simple form of pure animal charcoal free from impurities. Care should be exercised in adopting any complex or mysterious compound, abnormally quick in action and a supposed saver of time, for while some mixtures are quick in biting, and many of them are good enough, the speed is often obtained at the expense of the metal, where the presence of saltpetre or other fusible salt may develop soft spots which ultimately leads to scrapping the piece. In the selection of a compound it is well to keep in mind the work expected to be done by the material on the steel under treatment, and to remember that when the whole is heated to a certain temperature the desired results are simply to convert the outer skin of the steel from a mild steel to a hard one by the absorption of carbon, and experience proves that simplicity at this point makes for the best and most reliable results.

In packing the box, the mixture should first of all be thoroughly dried and reduced to a very fine powder, for if the particles are large it allows a lodgment of air between the particles, and as the presence of air is deleterious to the process, it is also evident that the larger the particles the more liability there will be for presence of air in the box. Having reduced the material to a fine powder, a layer of not less than 1½in. or 2in. is placed in the hardening pot and well pressed down. The articles to be cased are placed on the top of this at least 1½in. free from the sides, and having a similar amount of spacing between each article. Another layer of carboniser is placed on the top of the articles, about 1½in. deep, and the whole is pressed firmly down, care being taken in pressing down the carboniser not to displace any of the articles to be treated. This process is continued until the box is nearly full, the final layer of mixture being at least 1½in. deep, and coming almost flush with the top of the sides. The object of packing the box in this manner is to make the contents as compact as possible, consistent with a sufficiency of carboniser, and it follows that the more solidly a box is packed the less liability there will be for a lodgment of air around the pieces to be cased, or amongst the particles of carboniser. The lid is now placed loosely on the top, free from the sides of the box and tapped down until it is flush with the sides, a luting of clay round the lid as an effectual seal completes the operation of packing, the box being now ready for the carbonising furnace.

Sometimes a piece requires to have a portion left soft. This is usually done either by covering the portion with clay, painting it with a composition able to withstand the action of the carbon, or copper-plating the part to be left soft. If clay is the stopping-off medium it should be carefully pressed round the part to be left soft, care being taken to see that it adheres to the metal, and that it is quite dry before being placed into the box. The use of a fire paint enamel is another method, which, if carefully applied and baked before being packed in the box, will keep the carbonaceous gas from touching the part requiring to be left soft. The drawbacks to fire paint are principally the care that must be exercised to keep the articles free from rust or oxide before applying the paint, and the difficulty of its removal after carbonising. The third method consists of a fine coating of copper about two one thousandths of an inch thick electrically deposited on the parts not to be carbonised. This affords a protection provided the copper is free from porosity and a sufficient thickness is deposited. The danger here is the tendency for the copper to be porous and to allow minute surfaces to be exposed to the gases. This can be successfully overcome by keeping the piece in constant motion while being electrically treated. As will be seen, the foregoing methods, if carefully carried out, will eliminate the expensive procedure of turning off the casing before hardening, thus allowing the piece to be hardened direct without going back to the machine shop.

It is essential that all case-hardened articles be reheated before quenching. The reheating furnace should be a muffle heated by gas, as gas can be regulated with exactness to within a few degrees of the temperature required. It is not advisable to reheat in the casing furnace, as the two operations require different temperatures, and much more satisfactory and accurate work can be obtained by having the reheating furnace constantly engaged in this operation, as it can with more ease be kept at the temperature necessary for reheating. Furthermore, as reheating and quenching are the most critical parts of the process, it is much safer to have a furnace laid off for reheating, for besides the even temperature necessary, there is less chance of an excess of air in the gas mixture, a minimum of regulating being necessary after the muffle has reached the proper temperature. The question of excess of air is a very important one, as in the reheating process it tends to decarbonise the article, and instead of giving a glass-hard surface it would give a soft one.

Oil and water are the common quenching liquids employed, but in some cases, where the pieces are required to be specially hard, a brine solution is used. If oil is the medium employed it should be contained in as large a tank as possible, and if the operation of quenching is of such constancy as to appreciably raise the temperature of the liquid, special means should be taken to keep the oil at normal temperature. A very efficient way of keeping the oil cool is to circulate it by force pump through a coil of pipe immersed in cold running water. This method of cooling has the advantage of keeping the oil in constant circulation, and is better than a stagnant liquid, which is slow to give up its heat, and depends on circulation mainly from the movement of the articles being quenched. If a circulating coil is not available, the tank should be fitted with an outer shell in which cold water is circulated. A water inlet pipe fitted at the base, and an outlet pipe fitted at a point extreme from the inlet, will ensure a fair extraction of heat. If the oil is allowed to become unduly hot the pieces will take longer to cool, and will vary in hardness according to the temperature of the bath. Where water is the quenching medium the containing tank should also be large, and should have a good supply of clean cold water constantly running into the tank while work is being done. The inlet pipe should be at the bottom of the tank, as by this means natural circulation assists the hot water to reach the outlet, which should be near the surface of the quenching water. As pure water is an added security to the success of quenching, care should be exercised to see that the tanks are cleaned out periodically.

Some form of apparatus for registering the temperature of the furnace is a most valuable addition to the plant, and for consistent hardening is almost essential. One method of determining the temperature is by the use of fusible salts made up into cones to fuse at various temperatures. These cones at best give only a rough idea of the temperature, and the trouble associated with their use makes their adoption undesirable. Where anything like accurate results are required, the use of a pyrometer is essential. This point will be appreciated when one considers the consistency of the results which follow the adoption of a pyrometer.

A method of testing the hardness of the metal after case hardening is very useful. The ordinary method of testing a piece after hardening is with a file, and while this is a handy enough means to determine if the article is hard enough it gives no positive way of finding out if the piece is too hard or overheated. There are four or five excellent methods of testing hardness by mechanical means. The better known and most in use are the Brinell ball test and the scleroscope. The former is considered to be the most accurate hardness test, and

its value is evident from the fact that it is largely used for laboratory work. For factory purposes, however, the scleroscope seems to be a very suitable tool, as it is simple to understand, and can be easily operated with accuracy without any scientific knowledge. The constant use of the scleroscope, or other hardness measuring instrument, will at once appeal to those who strive for consistent results, as it provides an easy method of knowing positively the standard to which the general work in the hardening shop is being brought to.

The foregoing being a short synopsis of the equipment of a case-hardening plant from start to finish, we can now proceed to discuss the subject on more general lines. The question of the steel to be used is not within the province of this paper, though a passing word on the subject might not be out of place. The steel should be purchased from a reputable maker of case-hardening steel. It should be free from impurities and of uniform composition, capable of absorbing an equal amount of carbon in the case, while retaining a maximum amount of tenacity in the core. If the process is followed through with reasonable accuracy, and the steel is of reputable quality, very good results should accrue. A very common practice in case-hardening, which is luckily dying out, is to carbonise and quench on the one heat, the method employed being to remove the boxes after the carbonising period is finished, and empty the contents into a bath of water. Some, a little more careful, take out the articles singly and quench. While the latter practice is a little better than the first, both are bad, and lead to very grave irregularities, the case being quenched at too high a temperature, and the core robbed of all the inherent qualities of the original steel. The surfaces of articles treated thus are liable to chip or flake, and to have crystallised cores of little or no resistance. In no section of engineering has there been so much time and money lost than in case-hardening, this being largely due to the lack of definite data regarding the process, and the temptingly easy way out of the difficulty by shouldering the weakness on the steelmaker.

In case-hardening we have two steels to contend with, inseparably connected but different in composition. I mean the hard case and the soft core. We should endeavour to get the case to yield a glass-hard surface, with the core extremely tough and of silky fibre. The article should be capable of taking a severe bend without breaking. It has been found that a temperature of 950° to 1,000° C., if continued until the case is about $\frac{1}{16}$in. deep, will give a case containing about ·85 or ·90 per cent. carbon. When quenched after reheating this will give a scleroscope test of ·90 or ·95 hard, which is satisfactory. It has also been found that at a temperature not exceeding 1,000° C. the core retains a certain amount of toughness, which is lost if the temperature reaches 1,300° or higher, therefore a temperature between 950° and 1,000° C. has been adopted as a safe standard to carbonise at, it being quick enough for reasonable absorption and not high enough to destroy any of the properties of the steel.

Having a knowledge of the right temperature for carbonising, it remains now to fix the time requisite to yield a sufficient depth of case. It is difficult to give a determined time for this, so much depends on the size of the box, the depth of penetration required, the size of the articles, and the carbonaceous mixture in use, but we might roughly say that a box 12in. by 12in. by 6in. containing shafts $1\frac{1}{2}$in. diam. would yield a depth of $\frac{1}{16}$in. case in six hours, counting from the time the box is placed cold into the furnace, which has been heated to the required temperature. Of course it is evident that the larger the articles, the longer it takes to reach the stage of absorption, which usually commences when the temperature reaches 700° C., and as a large part of the time is taken up in heating the box and material to the requisite temperature, it is sometimes useful to know approximately when the reaction actually takes place. A mistake is often made in taking for granted that the heat has penetrated through the box when the sides and top are similar in colour to the surrounding brickwork, but we can safely say that the heat has not penetrated through the contents until the bottom of the furnace under the box is as hot and of the same colour as the sides and top of the furnace. As there has been an effort in some directions to tabulate the time taken to heat up boxes of various sizes, we might say the safest way to approximate the time taken to bring the contents to the same temperature as the furnace, is by opening the furnace periodically and carefully tilting the box with a bar to observe the colour of the furnace floor under the box. When the floor is of the same colour as the surrounding brickwork it can be taken that the heat has penetrated through the box, and it is reasonable to suppose a similar box will take a similar time. This operation, of course, could only be permissible for experiment, as it is not judicious to open the furnace or move the box during the carbonising period.

As a means of observing the depth of case and judging fractures, it is very good practice to place a piece of the original steel in the box, to be carbonised along with the work, care being taken to place it in some average position, preferably towards the centre of the box. This piece could, after the process, be broken, and would give a good indication of the depth of case on the articles. It is rather an important point to place the test piece near the centre of the box, or in a good average position, for if the article to be cased is large, and the test piece is placed near the walls of the box, it follows that the test piece, reaching the absorbent stage sooner than the larger and more remote part, will show a much deeper case and lead to inaccurate conclusions.

At the end of the carbonising period the boxes are withdrawn and placed on the floor in a dry place, where they are allowed to lie till perfectly cold without the articles in any way being disturbed. They are then taken from the box and dusted clean. If the box has been properly packed the surface of each article will show a rich grey or a bluish grey colour.

The pieces are now ready for reheating and quenching. Up to this stage the process can be successfully carried through without the aid of an instrument for recording the temperature, but, as the reheating is an operation demanding accurate temperatures within very close limits, the use of a pyrometer at this stage is a necessity for good and consistent results. It is very difficult to judge a critical temperature with the eye, and even after years of experience mistakes can be easily made. The best practice is to fit a pyrometer to each furnace, and in some cases, where a number of muffles are in operation, this is realised to the extent of having an operator constantly observing the recorded temperatures in a room laid out for this purpose. Communication with the man at the furnace is made usually through the medium of coloured electric lights controlled by the observer, each furnace being fitted with a white, a green, and a red light, within easy sight of the operator at the furnace. When the heating is correct a white light shows over the furnace. Immediately the temperature tends to rise the observer switches on the red light, and when the temperature tends to fall a green light is shown. By this means the operator at the furnace can regulate the temperature, and the chance of his getting away from the critical temperature is reduced to a minimum.

In reheating care should be taken to render the muffle practically air tight, as one of the drawbacks to case-hardening is the liability to decarbonise the articles in reheating through an excess of air either in the gas mixture or through the door of the furnace, thus producing a soft instead of a hard surface after quenching. The exclusion of air is a very important factor to watch in this operation, and to get over the trouble of decarbonising a method has been adopted with success whereby the medium of heating is through lead raised to the necessary temperature with gas or oil, and contained in deep pots round which the hot flames play, and in which a thermocouple is immersed to record the temperature of the bath. In this liquid the articles are immersed until they reach the temperature of the lead, and then quenched.

This method of reheating is very efficient, as the presence of air is excluded entirely in the process of heating, and the danger of decarbonising eliminated provided the articles are smartly quenched immediately they are taken from the bath. To ensure the success of this method the lead must be absolutely pure, as the presence of sulphur or other impurities will lead to faulty hardening and produces a scum on the surface of the liquid which adheres to the articles and is difficult to remove after quenching. A barium chloride solution can be used in the bath as a substitute for lead.

We may now consider the temperature required to obtain consistent results in reheating, and attempt to show the absolute necessity of keeping the operations of carbonising and hardening separate and distinct. It is a well-known fact that steel, whether cooled slowly or quickly, contains in its structure a definite condition peculiar to the highest temperature to which it was last subjected, and a realisation of this important factor in the treatment of steel at once suggests to us the fallacy of attempting to quench at any time but when the

temperature is rising, and the temperature within the critical zone. We must remember that in the process of carbonising, the steel has been raised to—and maintained at—a high temperature, and that at this stage it will bear evidence of overheating. If broken, it will show a very coarse crystallised fracture, breaking off short and brittle with little or no cohesion. When a piece of cased steel is slowly heated a certain critical point is reached, where a great molecular change takes place in the structure of the metal, and if the piece is quenched within reasonable limits of this temperature the steel will be restored to its original strength and tenacity. It has been found by experiment that a piece of ordinary carbon steel containing ·15 carbon reaches this critical stage when the temperature is about 845° C., and if we quench immediately after the molecular change has taken place we can reasonably expect the steel to be restored to its original condition. As it is safer always to go about 30° higher than the recalescent stage to ensure having passed the danger limit, the best temperature to quench at would therefore be 870° C., this would give us the core restored and able to withstand a bending force without breaking. The case, however, has a carbon content of ·90 carbon, the critical temperature of which is about 720° C., and to ensure a glass-hard surface of ·95 hard on the scleroscope the article would require to be quenched at this temperature.

We are now confronted with the problem of attempting to get a satisfactory case in conjunction with a fibrous core, the critical temperatures of the two showing a difference of 125° C. It follows therefore that the ideal method of procedure is to treat the article to the critical temperature of the core, namely, 875° C., and quench. This will give a silky fibrous core of great tenacity. The piece should again be reheated to the critical temperature of the case, which is 720° C., and quenched. A very hard surface will now be imparted to the case, and if the piece is broken it will show a close grey case, clearly defined from the soft fibrous core. It will be noted that the second quenching temperature being lower than the first, the molecular structure of the core remains undisturbed. We are indebted to Mr. David Flather, of Sheffield, for his research work, which evolved the double-heating process.

While it is not essential to double heat all pieces, this method is recommended where the articles are required to be dead hard and are subjected to hard work when put into commission. For ordinary purposes, however, satisfactory results can be obtained by compromising between the two critical temperatures. This can be arrived at best by finding out which of the two will result in least risk, and adopting the resultant temperature as best and safest for the work, if single quenching is to be adopted. If we heat to the critical point of the case, we obtain a glass-hard surface with a coarse crystalline core, the steel not having reached the temperature where the molecular change takes place in the core. If we heat to the critical temperature of the core, we have overheated the case, but we obtain the proper texture in the centre of the metal. Bearing in mind the fact that we wish to obtain a combination of hardness and strength, and as the strength lies almost entirely in the core, it follows that the best results will be arrived at by heating and quenching at 875° C., which ensures the core being of maximum strength, and though we lose a little strength and hardness in the case, it is very little, and will not interfere with good practical working results, showing a scleroscope test of close on ·90 hard. While we can get satisfactory results from one reheating and quenching, we trust it has been made plain from the foregoing that nothing but difficulties and failures will accrue from dipping direct from the casing pot, as no piece treated in this way can be rendered sufficiently hard in the case or tough in the core.

It will be evident from the figures given that the question of temperature depends entirely on the percentage of carbon contained in the steel and the endeavour has been, in giving definite temperatures, to choose an ordinary commercial carbon steel as a guide in this important operation, there being no doubt that the steel used has a very great deal to do with the ultimate results obtained in hardening.

Regarding the question of distortion, a great deal depends on the size and shape of the articles under treatment and on the direction in which the immersion takes place. Heating to a temperature of 750° before any work is put on the piece and allowing it to slowly cool is a very good method of relieving any hammer or stamping strains, especially in the case of drop forgings. In accurate work, such as bevel wheels, it is good practice to heat the wheels after the gashing cut has been performed on the teeth, which ensures the finished wheels being very true after hardening.

Some very good jigs are in use for keeping bevel wheels and similar parts from distorting in hardening. These jigs are made to grip the wheel at the teeth, the portion coming in contact with the back of the wheel being castellated to allow of free circulation of the liquid round the piece. The binding medium is usually a large taper cotter, which can quickly locate and lock the wheel for quick immersion. A very effectual method of accelerating the cooling is to fix the wheel and jig to a plate, which is reciprocated up and down in the liquid by means of a pneumatic piston, the operation being very quick indeed.

A good deal of discussion has taken place as to the proper method of immersing shafts to prevent their bending during hardening, and while common sense and experience very quickly suggest the best methods of dipping, there is always more or less a tendency for shafts to depart from a straight line. If the cores are brittle many will be broken in the process of straightening, which is another reason for condemning the practice of quenching direct from the casing pot, but if the shafts have been reheated and the cores restored to their original toughness, little difficulty will be experienced in straightening, and very few will be scrapped. A fair measure of success in judging fractures can be gained by remembering that the steel under treatment contains a record of at least the last temperature to which it was subjected, and if a good quality of steel is used the fracture will show in good measure whether the piece under observation has been treated properly or not. Thus, if the case shows a clearly defined white grain and the core is grey and fibrous, the inference can be made that the quenching temperature is right. If the case is white and the core coarse crystalline, breaking with a short fracture, it can be taken that the reheating has been to too low a temperature, and under the temperature where the molecular change takes place in the core. A piece quenched direct from the casing pot will usually show a very coarse crystalline core with an ill-defined case, the metal being more or less ruined. These three instances are perhaps the most frequently found in practice; the use of test pieces, however, will soon make one familiar with the most vital evidences to look for regarding good or bad work, and if it leads to classifying the various fractures an invaluable service for subsequent accuracy will be rendered to the hardening shop.

In conclusion, we might say that the study of case-hardening, while presenting minor difficulties, can be satisfactorily carried through if entered into in a proper spirit. The process is full of interesting problems, which a good equipment makes easy of solution. When once a proper system has been definitely established, nothing but success will follow if regularity is observed in carrying out the various operations from the heating of the carbonising furnace to the final quenching of the piece.

Power from Waste Heat.—West Hartlepool, which claims to be the first municipal authority to produce electricity by means of waste heat, will shortly open its new generating station. This station will pcssess twice the capacity of the old, and its two turbo-generators, each of 1,500 kw., will be driven by exhaust steam from the furnace blowing engines of the Seaton Carew Iron Company, adjacent to whose works it is built. In return for their exhaust steam, which has hitherto been blowing to waste, the Seaton Carew Iron Company will receive the supply of electric current they need at their works. The new turbines can work with either exhaust or high-pressure steam. Should the supply of exhaust steam not be available, either through a breakdown of the blowing engines or through the ironworks being idle, a supply of high pressure steam will be obtainable from the boilers at the works of the Seaton Carew Iron Company. The exhaust steam, after leaving the turbines, will be condensed, and the water will pass through a Lea recorder back to the boilers of the ironworks. To supply the condensers with cold water three cooling towers have been erected, each capable of cooling 115,000 galls. of water an hour. The total expenditure involved in connection with the new scheme is £38,795, the plant alone having cost £30,000. The old generating station will be maintained as a stand-by and also as a town sub-station.

A NEW LOCOMOTIVE TESTING PLANT.*

BY PROF. EDWARD C. SCHMIDT.

THE locomotive testing plant has placed at our disposal a means for studying the locomotive which has made good the deficiencies of road testing. The first locomotive testing plant was built 21 years ago at Purdue University. It was designed by Dr. W. F. M. Goss, who was at that time in charge of the schools of engineering at that institution. Not the least of the good influences of this plant is the encouragement which its success has offered to other experimenters to establish similar laboratories. At present there are four such testing plants in this country and two in Europe.† An addition to the small number of existing plants is of interest, and the present article describes the new plant of the University of Illinois, which has recently been completed. The Illinois legislature at its last session included among its appropriations for the university £40,000 for new buildings for the College of Engineering, and it was decided to use this for a transportation building and a locomotive laboratory for the department of railway engineering. The plant has been designed with the intention of making it suitable to test new designs of locomotives as they appear, in the confidence that the railways and builders would be willing to keep upon the plant locomotives of recent design, concerning whose performance information is desired. Figs. 1 and 2 show the general arrangement of the plant.

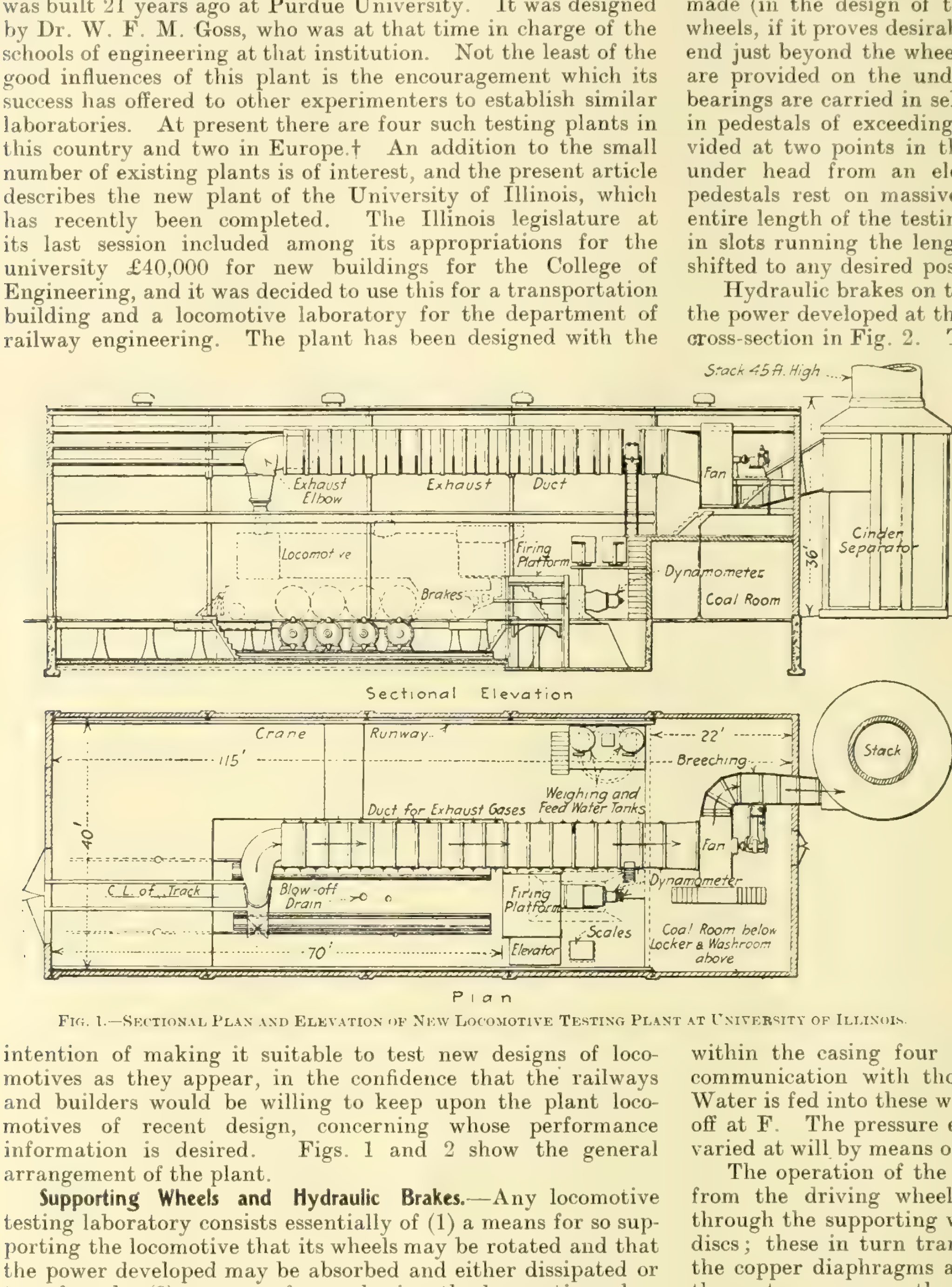


FIG. 1.—SECTIONAL PLAN AND ELEVATION OF NEW LOCOMOTIVE TESTING PLANT AT UNIVERSITY OF ILLINOIS.

Supporting Wheels and Hydraulic Brakes.—Any locomotive testing laboratory consists essentially of (1) a means for so supporting the locomotive that its wheels may be rotated and that the power developed may be absorbed and either dissipated or transferred; (2) a means for anchoring the locomotive when so mounted and for measuring the tractive effort developed; (3) means for supplying and measuring coal and water; and (4) means for disposing of the gases and exhaust steam. The supporting mechanism in this plant (as in all others) consists of wheels whose position may be varied to conform to the spacing of the locomotive's driving wheels. The supporting wheels are 52in. diam., provided with plain tyres, and mounted on 11½in. axles, the axles and tyres being of heat-treated carbon steel.

The use of 52in. supporting wheels involves rotating speeds as high as 500 revs. per minute in testing high-speed locomotives. Such speeds may give rise to difficulty in the operation of the bearings, although they have been designed with regard to these conditions. However, provision has been made (in the design of the bearing pedestal) for using 72in. wheels, if it proves desirable. The axles are supported at each end just beyond the wheels, in bearings 9½in. by 20in., which are provided on the under side of the journal only. These bearings are carried in self-aligning shells which are supported in pedestals of exceedingly heavy construction. Oil is provided at two points in the bearing cap, where it is supplied under head from an elevated supply tank. The bearing pedestals rest on massive cast-iron bedplates which run the entire length of the testing pit, and as the bolt heads are held in slots running the length of the bed, the pedestals may be shifted to any desired position on the bed.

Hydraulic brakes on the axles provide means for absorbing the power developed at the driving-wheel rim, as shown by the cross-section in Fig. 2. These are of the type used in all other American testing plants, and were designed by Prof. G. I. Alden, of Worcester, Mass., under general specifications prepared by the designer of the plant. One of these brakes is mounted on each end of each supporting axle. Each brake (Fig. 3) consists essentially of three cast-iron discs A, which are keyed to the supporting axle, and which rotate between water-cooled copper diaphragms B carried in a stationary casing C. The cast hub D and the three discs form an integral rotating element which is keyed to the axle and turns with it. The casing and its diaphragms are prevented from rotating by means of links attached to the bedplates. The diaphragms form within the casing three compartments within which the cast-iron discs rotate. The surfaces of the discs and of the diaphragms are lubricated by oil fed in at the periphery of the discs and taken off at the hub. The diaphragms form also within the casing four water compartments which have no communication with those within which the discs rotate. Water is fed into these water compartments at E, and is taken off at F. The pressure existing in these water spaces may be varied at will by means of suitable valves in the brake piping.

The operation of the brakes is as follows. Power received from the driving wheels of the locomotive is transmitted through the supporting wheels and axle to the cast-iron brake discs; these in turn transmit it by friction to the surfaces of the copper diaphragms against which they rub. By varying the water pressure, the friction between the discs and the diaphragms may be varied in accordance with the amount of power to be absorbed. The entire power of the locomotive is thus dissipated at the surface of the diaphragms and carried away as heat in the water which circulates through the brakes. Each brake is designed to develop a resisting torque of 18,000lbs. ft., which is more than is likely to be transmitted to it by the most heavily loaded locomotive driver.

The above machinery, which serves to support the locomotive and to absorb its power, is all carried on a slab of reinforced concrete 93ft. long and 12ft. wide, varying in thickness from 3½ft. at the front to 5ft. at the rear. It is surmounted at the rear end by a pyramidal pedestal which serves as the anchorage for the dynamometer.

Traction Dynamometer.—The locomotive is anchored by a massive drawbar to a dynamometer of the Emery type, which consists essentially of a weighing head and a weighing scale. Within the head is an oil chamber with a flexible wall, which receives and balances any force transmitted from the loco-

* Paper read before the Western Railway Club, Chicago, March 18th, 1913 and reproduced from "Engineering News."

† The Purdue plant, erected in 1891, was followed in 1894 by a temporary plant, at South Kaukauna, Wis., on the Chicago & North-western Ry., designed under the direction of Mr Quayle This was succeeded in 1895 by a permanent plant, designed by Mr. Quayle and erected at the C. & N. W. Ry. shops in Chicago. In 1899, Columbia University having been given a locomotive by the Baldwin Locomotive Works, provided for a testing plant which is erected in the mechanical engineering laboratory. In 1904, the Pennsylvania R.R. installed at the St. Louis Exhibition what was at that time the largest and most elaborate plant yet built This later was removed to Altoona, Penn., where it has been in almost constant operation since. In 1904 there was also erected in the Putiloff Works at St. Petersburg, Russia, a similar plant designed by M. V. Coloboloff and S. T. Smirnoff. The following year there was erected in England a plant under the direction of Mr. Churchward, of the Great Western Ry., at the Swindon works of that company.

motive. The pressure of the oil in this chamber varies with the load and is transmitted through a copper tube of small bore to a similar smaller oil chamber, the pressure within which moves the beam of a substantial but very sensitive scale. The force transmitted to the dynamometer is thus weighed. In design this instrument is very similar to that of the original dynamometer furnished for the Purdue University plant. Its capacity, however, is about four times as great, namely, 125,000lbs.* Up to this limit it will measure with great accuracy any force transmitted to it from the locomotive.

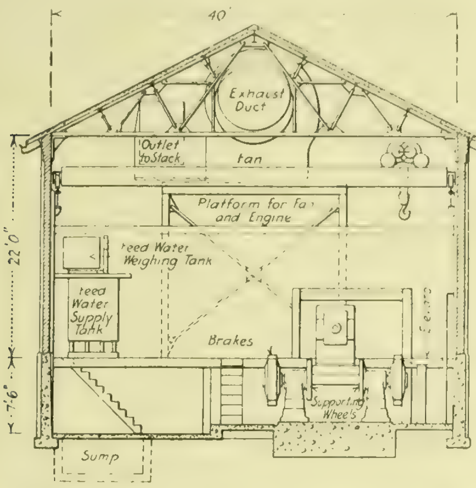


FIG. 2.—CROSS SECTION OF LOCOMOTIVE TESTING PLANT.

One feature of special interest is that the adjustment of the poise weight on the scale beam is accomplished automatically. This has permitted (for the first time in this type of instrument) the development of a device whereby the amount of the force weighed on the scale is autographically recorded.

The capacity of this instrument is about 15,000lbs. in excess of the greatest tractive effort which could be imposed upon it by even the most powerful Mallet locomotive now in existence. The plant can test the largest of these Mallet engines; and at the same time all the equipment and the building itself have sufficient margin in size and capacity to allow for a very considerable increase in size, weight, and power of locomotives.

Determining Exhaust Gases and Cinders.—In providing means for disposing of the exhaust gases, new problems were presented and new solutions have been reached. In view of the importance of determining accurately the total fuel lost in the exhaust gases, it was decided to try to incorporate some means for entrapping all of the solid matter contained in the gases passing from the smoke stack. This purpose has been served previously by collecting in a sampling tube the solid matter which passes a small section of the exhaust-gas stream, and

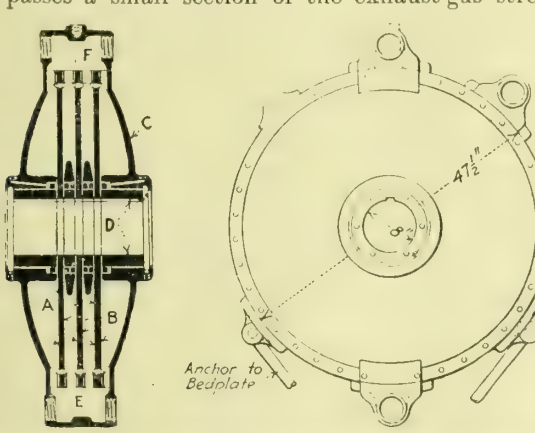


FIG. 3.—ALDEN HYDRAULIC ABSORPTION BRAKE FOR LOCOMOTIVE TESTING PLANTS.

pro-rating the loss of solid fuel thus determined over the entire stream section. This method is not always convenient, and under certain conditions its results are open to doubt.

A spark trap or cinder collector which would pass the total volume of gas and exhaust steam from the largest modern locomotive when working at high power would be too large to be located conveniently within the building. A second fundamental consideration in designing the exhaust system was the necessity of providing a stack of sufficient height to ensure that the gases would be discharged at such a height as to prove inoffensive to occupants of neighbouring residences and university buildings. It was decided that this would require a stack about 8ft. diam. and at least 80ft. high. Further study made it apparent that these two features could be embodied in one structure. This has been accomplished by the combined cinder separator and smoke stack which is shown in Fig. 4 and is located outside of the laboratory.

The exhaust gases as they emerge from the locomotive stack are discharged into a steel exhaust elbow which carries the gases up and over to a horizontal duct running through the roof trusses. The gases are drawn through this elbow and duct by an exhaust fan. Probably the heaviest cinders will be dropped in this duct but the velocity within it is such that all but the heaviest particles will be carried through the fan. Whatever does accumulate here may be removed through traps provided in the bottom of the duct, and weighed.

The gases and solid matter passing through the fan are delivered by a breeching or flue to the separator. They enter this at A, and in order to leave they must pass downward and around the sleeve B. In so doing they are given a whirling motion which causes the cinders to move toward the wall, along which they drop to the hopper C, while the gases pass downward and out to the stack through the mouth of the sleeve. The cinders collecting at the bottom of the hopper are drawn off and weighed. This separator is surmounted by a 45ft. radial-brick stack.

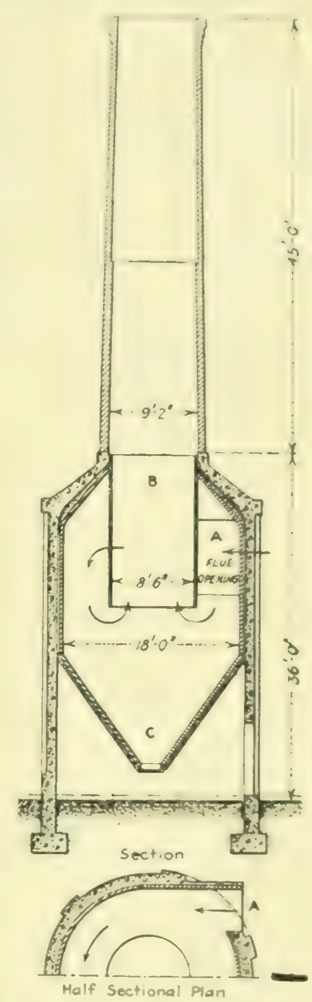


FIG. 4.—STACK AND CINDER COLLECTING CHAMBER.

The corrosive nature of the mixture of exhaust gas and steam has made it necessary to avoid the use of metal. The exhaust elbow within the building necessarily has been made of steel, and will need occasionally to be renewed. The duct and fan breeching, however, are of asbestos board which will resist corrosion. The duct is 7ft. diam., and made up of separate sections so that its length may be varied. The fan has a runner 6ft. diam., and will pass, at maximum speed, 140,000 cub. ft. of gas per minute. The breeching has a minimum cross-sectional area of about 24 sq. ft.

The outer shell of the separator is built of reinforced concrete, lined with hard-burned red brick (as is the hopper). Between the lining and the shell is a 2in. air space to protect the shell from undue heating. Any leakage of gas into this space is vented to the outside air through openings in the shell, which serve also to circulate cool air through the air space. The inside sleeve and hopper are of reinforced concrete. The stack is unlined, but is laid up in acid-proof cement.

Institution of Mining Engineers.—The 58th general meeting of the Institution of Mining Engineers will be held in the rooms of the Geological Society, Burlington House, on June 5th, when the following papers will be read or taken as read: "Recent Methods of the Application of Stone Dust in Mines," by Dr. W. E. Garforth; "The Re-opening of Norton Colliery with Self-contained Breathing Apparatus after an Explosion," by Mr. J. R. L. Allott; "The Heat Produced in the Slow Oxidation of Coal at Ordinary Temperatures," by Mr. F. E. E. Lamplough and Miss M. Hill; and "Insulated and Bare Copper and Aluminium Cables for the Transmission of Electrical Energy, with Special Reference to Mining Work," by Mr. B. Welbourn.

* The maximum capacity of the dynamometer used in the Pennsylvania R.R. plant at Altoona is 80,000lbs.

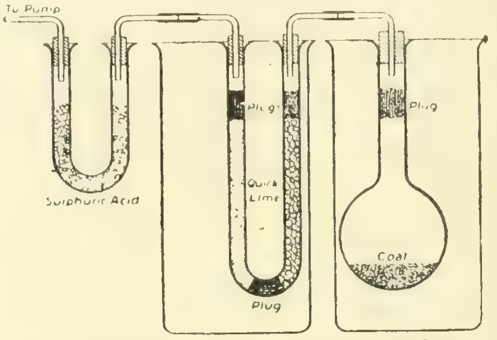
DETERMINATION OF MOISTURE IN COAL.

At a meeting of the Institution of Mining and Metallurgy held on May 22nd, Mr. P. L. Teed, in a paper on "The Determination of Water in Coal," pointed out that in the simple drying method universally employed for determining the percentage of moisture in a fuel, reactions other than the simple volatilisation of the water take place, which may materially affect the accuracy of the result, and described an accurate and rapid though more complex process for determining the percentage of moisture in fuel.

The method universally employed is that of taking a weighed quantity of 80-mesh coal, drying the same in a steam oven, and recording the loss in weight, but sources of inaccuracy exist due to the following reactions: (*a*) Oxidation of pyrites making the result too low; (*b*) volatilisation of matter contained in the coal making the result too high; and (*c*) oxidation of the coal itself making the result too high.

The following method has been evolved: The apparatus illustrated herewith consists of a 100-cc. pressure flask, a "U" tube of about ½in. bore, and a sulphuric-acid drying tube, all of which must be capable of withstanding atmospheric pressure; besides these, sound rubber corks and some form of vacuum pump are necessary. With regard to the latter, the Sprengel water vacuum pump worked off the main supply has been found to give a reduction in pressure equal to about 725 mm., and to be in every way satisfactory.

The employment of the apparatus is as follows: In the dry weighed flask a quantity of the finely divided coal (80-mesh) is placed, and the weight of the same determined by difference; this flask is connected to the weighed "U"



Apparatus for Determining Moisture in Coal.

tube, whose limb nearest the flask is filled with lump quicklime, while that more remote is filled with finely-ground quicklime; this "U" tube is connected to the sulphuric acid drying tube, which is itself joined up to the Sprengel pump with an intervening tap. The pump is started and a vacuum gradually created (the speed of the outcoming gas being shown by the bubbles in the sulphuric acid drying tube); the flow of water through the pump is gradually increased, until a vacuum of about 700 mm. is created; then boiling water is poured into the beaker in which the flask containing the coal is standing, while to the beaker in which the lime tube is situated a boiling aqueous solution of either sodium chloride or calcium chloride is added, care being taken that the corks of the tube are not wetted with the solution.

The reactions taking place are as follows: Under the reduction of pressure and at a temperature of the boiling water surrounding the flask containing the coal, the water in the coal, together with volatile matter varying with the nature of the coal, distils off and passes into the lime tube, where, in accordance with the following equation—

$$CaO + H_2O = (Ca,OH)_2,$$

the water originally in the coal is chemically retained, while the other volatile matter from the coal, owing to the absence of any chemical affinity for the lime, and the higher temperature of the lime tube (due to its being surrounded by a boiling aqueous solution of sodium chloride or calcium chloride), passes through to the sulphuric acid drying tube, where some of it is retained, discolouring the sulphuric acid, while other portions pass through to the pump.

At the end of about half an hour, the whole of the water having passed from the coal to the lime tube, the tap adjoining the vacuum pump is turned off, the beaker of boiling water surrounding the coal flask is removed, and the air gradually let back through the sulphuric acid drying tube into the apparatus; then the apparatus is taken to pieces, the lime tube washed, wiped, placed in a desiccator to cool, then weighed, the increase in weight noted (this increase is solely due to water from the coal) and the percentage of water in the coal calculated.

In the new method the two errors due to oxidation no longer exist, because the water is distilled from the coal in the absence of air, and consequently no oxidation can take place; with regard to the error due to volatilisation of matter in the coal, something more must be said, for the volatilisation still takes place, but since the temperature of the quicklime tube is higher than the coal itself, no condensation can take place in this tube unless chemical action takes place.

When determining the percentage of moisture in an anthracite, it was found that the increase in weight of the drying tube was greater than the loss in weight of the anthracite in the coal flask, by an amount far greater than would be accounted for by the fact that the aqueous vapour in the air originally in the apparatus would be absorbed by the drying tube; naturally it was at first supposed that there must be some leak in the apparatus between the coal flask and the drying tube, but this, on performing a blank experiment, was not found to be the case. The experiment was repeated, using anthracite in the coal flask, and it was found that while the increase in weight of the drying tube was equal to 2·78 per cent. of the anthracite employed, the decrease in the weight of the anthracite in the flask was equal to 2·52 per cent. This curious fact having been undoubtedly established, the author sought for some explanation of it, and could but conclude that when the water left the coal under the influence of the reduced pressure and heat, it left it in the physical condition of charcoal, capable, like charcoal, of absorbing many times its own volume of gas.

THE SEASON-CRACKING OF BRASS.

The season-cracking of brass is far more prevalent than the majority of people believe. It is not difficult to find good examples of it, although the majority of people are quite unfamiliar with the appearance or the fact that there is any such phenomenon. It is one of the "diseases" of brass and is not a new ailment, but has been in existence ever since objects have been made of brass sheet.

The season-cracking of brass, so far as known, occurs only on brass or other alloy that has had some work done upon it. The metal must have been rolled, drawn, spun, or treated by some other mechanical process. The cast metal which has not been worked at all, is apparently free from it. It is sheet brass articles that give the most trouble, perhaps, because they are more extensive than other forms of this metal, and it is on such articles that season-cracks may be found more than on any other form of brass.

Brass is not the only copper alloy which season-cracks, as the tin bronzes and aluminium bronzes are likewise subject to it. The yellow brasses, however, are the ones which are subject to it the most and this alloy seems to be more apt to crack under the right conditions than any other copper alloy. The fact that other copper alloys are subject to season-cracking indicates that the phenomenon is a physical and not a chemical one.

It is believed that the chemical composition of the brass or other alloy is not in any way responsible for its season-cracking, but that the whole question resolves itself into a matter of influences beyond the mixture itself. It may be outside influences, or it may be strains in the metal. In the majority of instances strains are the cause of the cracking, but ammonia and other chemicals evolving it will produce it.

Season-cracks in metals are those which form after the article has been in use for some time or "seasoned." The cracks form spontaneously without any apparent reason and this very fact renders the phenomenon so mysterious and perplexing. It has often been said that season-cracks are the most exasperating and perplexing of all the ills to which brass is subject, for the reason that they occur without any apparent cause and after the brass has been in use for some time. Were it to occur right away after the goods had been made, the matter would not be as bad, but to take place after they have been in use and no outside influence brought to bear on the brass, renders the subject more perplexing and mysterious to the user.

When season-cracking has been found on a brass article, the owner may take it back to the dealer from whom he bought it, who in turn sends it to the manufacturer for an explanation. The maker, of course, brings the matter to the attention of the brass rolling mill which turned out the brass sheet or other form. He frequently threatens to bring suit against the mill for damages caused by the cracking of the brass, and it seems unquestioned that the fault lies in the brass. The rolling mill proprietor is naturally perplexed and hardly knows what to say or what to do. Here is the case of his brass which cracked open and the evidence is against him. He may adjust the matter with the maker of the goods who used his brass, but he should not have done so, as the difficulty is one for which he is never to blame.

Up to the present time, our knowledge of the causes of season-cracking indicates that there are two which may be recognised as producing it: (1) Strains in the metal of which the article is composed; (2) ammonia or compounds generating it.

The first, or strains in the metal is, by far, the most common cause and it is the one that is responsible for nearly all the season-cracking encountered. Ammonia, however, will produce it and is often the cause of it.

Strains in the Metal.—Cold-worked metals always have strains in them, of course, and if these strains are uneven, then cracking is apt to result. This cracking may result immediately or after a time, depending upon conditions. Fire-cracking is only a modification of season-cracking and is caused by the strains set up in the metal by the heat. It occurs, for example, on German-silver sheet that has not been "broken-down" sufficiently, or, in other words, by using too light a "pinch" in rolling it. The outside is worked and the inside is not to any extent. The metal, therefore, when annealed has uneven strains set up in it and cracks result. In season-cracking, too, the same thing follows, although not immediately. There are uneven strains in the metal and it takes time for them to act. It has been found that drawn metal that is evenly worked will not season-crack unless by means of ammonia.

As the majority of season-cracking is caused by strains in the metal, let it be explained how this can happen. It will be found that drawn sheet brass shells are a very frequent source of this difficulty. The shell is drawn up in a press by means of a punch and die. The relation of the punch to the die may be such that the brass sheet is drawn more on one portion than the other and results in an uneven strain in the drawn shell. This presence of uneven strains is the cause of the season-cracking. Strains may exist in the drawn shell, and if they are uniform no harm results; but if they are uneven, then season-cracking may follow.

The presence of the uneven strains in drawn brass shells is the common source of season-cracks and nearly always, if not entirely, results from imperfect die work in the press. There are two methods, one might say, of making a shell in a press. One is by the simple forming by means of the punch and die, and the other is by actually drawing the shell and stretching the metal. It is the forming of the shell and not stretching the metal that is the dangerous kind of press work. It always results in an uneven strain being set up in the drawn shell. If, however, the shell is actually stretched and the metal worked as much as possible in the press, the strains produced are even and season-cracking is not apt to follow.

Effect of Ammonia.—It has now been well established that ammonia or compounds evolving it will cause brass to season-crack. Impure calcium carbide, such as now sold for generating acetylene gas, gives off ammonia when water comes in contact with it and at the same time that the acetylene gas is generated. This is the cause of the season-cracking of acetylene generators. It is not difficult to find very many instances of these acetylene generators which have cracked, and it is believed that the ammonia generated from the calcium carbide is the cause. Ammonia gas will also cause brass to season-crack, and compounds which generate ammonia upon standing likewise produce it. One of the frequent causes of the cracking is the excretions of animals (which, of course, generate ammonia). When they come in contact with the brass, season-cracking will usually result. Many cases of this kind are on record in which animal excretions have been the cause of the season-cracking of brass. Why ammonia should cause it is unknown, and it is one of the mysteries of season-cracking. It may be said that crystallisation and season-cracking, in the case of brass, seem to be the same as the appearance of the fracture is the same in each case. When brass season-cracks, the fracture is always coarse and crystalline.

Summary.—The various causes of the season-cracking of brass may be summed up as follows:

(1) That the chemical composition of the brass has no direct bearing on the season cracking.

(2) That uneven strains are the usual cause and that they are produced by imperfect press work on the brass article.

(3) That all copper alloys are subject to it.

(4) That ammonia or any compound evolving ammonia upon decomposition will produce it.

(5) That season-cracks are more apt to appear in yellow brass than in any other copper alloy.

(6) That the brass rolling mill is rarely at fault for the season-cracks and the maker of the brass article in the press is the one who should be blamed, except in the case of ammonia when, of course, the user of the brass article is responsible.

In conclusion, let it be said that the principal cause of season cracking is imperfect die work, so that internal and uneven strains are set up in the article itself. As one expert manufacturer of brass goods has expressed it, the brass should be "stretched" in the drawing operation and not merely "ironed out" or formed. He states that before this was known, many barrels of drawn brass shells were made by simple "forming," so to speak, and they all season cracked within a few days on standing in the barrels after making. The dies were then made over, so that the metal was stretched in the press operation and no season-cracking of the shells followed.—"The Brass World."

THE LATE DR. J. T. NICOLSON.

It is with deep regret we have to announce the death, at his residence at Macclesfield, on Tuesday last, of Dr. J. T. Nicolson, Professor of Mechanical Engineering in the Manchester University. He suffered a serious breakdown in health some 12 months ago and it was hoped that a lengthy holiday would restore it. He did recuperate sufficiently to resume his duties to some extent, but it was evident to his friends that he was seriously stricken, though few expected the end so suddenly and so soon. Dr. Nicolson commenced his engineering career in some engineering shops on the Tyneside and then went to the Edinburgh University, where he took his degree of Doctor of Science. Subsequently he studied at Munich, and afterwards received a teaching appointment at Cambridge University. This he relinquished to take up a lectureship in the McGill University, Montreal. In 1899, at the request of the authorities of the Manchester School of Technology, he was appointed Professor of Mechanical Engineering, and it was in connection with this position that he will probably be best known to many of our readers. As first professor he was responsible for the design of the magnificent laboratories with which this well-known institution—now a component part of the Manchester University—is equipped. During the last year or so of his life he was deeply interested in the special development of this laboratory for research work in connection with internal combustion engineering, and made some extensive enquiries on the Continent, chiefly in Germany, with this object. He strongly urged that Manchester should be made the centre of research work in this particular field, and it may be added that preparations for a new laboratory for this purpose are in active progress.

The first work which brought Dr. Nicolson's name before the engineering profession was a joint investigation conducted by him and Prof. H. L. Callender on cylinder condensation, and which was embodied in a paper contributed to the Institution of Civil Engineers. There was a considerable difference of opinion as to the actual physical changes which took place in the steam admitted to the cylinder and of the precise way in which a certain portion of the heat passed to the condenser, but it was generally assumed that it was condensed in the first instance on the cool walls of the cylinder. The research is a classical one, and excited universal admiration for the painstaking care with which the details of the investigation were worked out. The authors claimed to have proved by their

exhaustive experiments that only a portion of the missing steam was condensed on the cylinder walls and that much of it leaked past the valves direct to the condenser without doing useful work. Although this conclusion is not universally accepted, it is generally agreed that serious leakage may occur in this way, and the attention given to the fact has no doubt contributed largely to improved steam-engine economy.

A few years ago it may be remembered that the question of high-speed cutting tools came prominently forward in connection with the demonstrations of the American engineers, Messrs. Taylor and White, of the extraordinary performances possible with their special steel, which formed such a prominent feature at the last Paris Exhibition. The secret of the composition of the steel was revealed by their patent, but there was a complete absence of reliable data necessary for the practical design of machine tools capable of using it. The "Verein Deutsche Ingenieure" made a series of experiments in 1901 which threw some light on the subject, but it is to the classical investigations of Prof. Nicolson, commenced in the following year at the Manchester School of Technology under the auspices of the Manchester Association of Engineers, that engineers are indebted for the detailed information which they now possess. These were embodied in a paper presented to that association, and their practical bearing on the design of lathes was subsequently published in a joint work by him and Mr. D. Smith.

About six years ago Dr. Nicolson created somewhat of a sensation in boiler engineering circles by bringing into prominence a principle first enunciated by the late Prof. Osborne Reynolds regarding the question of heat transmission between the furnace gases and the water inside the boiler. Without going into details, it may be stated that Reynolds showed that the rate of transmission after a certain velocity was reached was proportional to the velocity. Practical considerations in respect to access and inspection had, however, deterred boiler designers and makers from applying this principle in actual work, and, in the opinion of Dr. Nicolson, wedded them to conservative forms and prevented them from realising the economy which was available. To demonstrate his views he constructed several experimental boilers and made a series of tests which fully corroborated what he described as Reynolds' law. The records of these tests and his opinions with respect to them led to a good deal of discussion, though the practical difficulties in the way of applying Reynolds' law have up to the present proved too serious to induce boilermakers to depart from established designs, though the future may perhaps reveal some way of surmounting them. Everyone, however, testifies to the originality and courage of Dr. Nicolson in demonstrating his ideas, and the engineering profession, as well as the Manchester University, is the poorer for his loss.

Strike of Staffordshire Tubemakers.—During the past few days the strike of operators engaged in the tube trade at Walsall and Wednesbury has extended until now there are some 6,000 men out. At Wednesbury twelve works are shut down employing 4,500 hands, and at Walsall four works employing 2,000. The men are striking for a 23s. minimum, and 10 per cent. increase to piece workers.

Launch of the Cruiser "Birmingham."—There was recently launched from the Elswick Yard of Messrs. Armstrong, Whitworth, & Co., Ltd., the light cruiser "Birmingham," built for the British Navy. She is the third vessel of her type to be launched from the Elswick yard. The "Newcastle" was the first of the Town or City type of cruiser; she was launched in 1910, and in the following year the "Weymouth" was built. The "Birmingham" is the largest of the three. She is 430ft. long, with a beam of 50ft., and a draught of about 16ft. Her displacement tonnage is 54,400. She is fitted with Parsons turbines, giving her 25,000 h.p., and a speed of at least 26 knots. The "Birmingham's" armament consists of nine 6in. quick-firing guns of the latest pattern. There will be numerous other smaller guns, and a full torpedo equipment, including two 21in. submerged tubes. Along the water-line runs a 3in. belt of armour. The vital parts of the ship, such as the boilers, powder magazines, and engines, will be protected by a 2in. steel deck. Her cost is put at £351,415, the cost of her guns alone being estimated at over £20,000.

INDUSTRIAL AND TRADE NOTES.

Closing of a Scottish Ironworks.—On Friday morning last week operations ceased at the Clifton Ironworks, Coatbridge, belonging to the Scottish Iron and Steel Company, and as a result fully 300 men have been thrown idle. No definite information was given to the men as to when the works would be restarted, but owing to the apparent scarcity of orders among the works associated with the above firm, it is feared that the Clifton Works may be closed down for an indefinite period. The Clifton is the second works which has been closed.

Mine Inspection Changes.—On the retirement, at the end of this month, of Mr. J. D. Atkinson, his Majesty's inspector of mines, the present Newcastle and Durham mines inspection districts will be amalgamated to form the northern mines inspection division. Mr. J. R. R. Wilson, inspector now in charge of the Liverpool and North Wales district, has been appointed to be divisional inspector in charge of the new division; and Mr. A. D. Nicholson, now in charge of the Durham district, has been appointed to take charge of the Liverpool and North Wales district, in place of Mr. Wilson.

The Rating of Watches.—In the report for the past year of the National Physical Laboratory, reference is made to the rating of watches. This interesting work was previously carried on at Kew, but was transferred to Teddington in November last. According to the report the number of watches entered for test was 473. The number reaching the class A "especially good" standard was 87, and 24 obtained 90 marks or more out of a possible 100. Out of the 24 watches only two were by London makers, the majority coming from Geneva. The first place was taken by a keyless, double-roller, going-barrel, bar-movement, lever watch with Guillaume balance sent by Paul Ditisheim, La Chaux de Fonds. This watch obtained the remarkable total of 96·1 marks, or 1·2 marks more than were awarded to a watch submitted by the same maker in 1903, which has hitherto held the record.

Proposed Egyptian Hydro-Electric Power Plant.—The Egyptian Government is, we learn, considering the development on a large scale of the power at present running to waste through the Assuan Dam. The scheme under consideration provides that the power afforded by the head of water maintained in the dam should be utilised to drive turbines, which in turn would enable dynamos to develop electric power. The amount of power thus afforded would be immense, but it is stated that the Government will probably only set up a comparatively small installation in the first instance, as a scheme so large as to take advantage of all the water passing through the dam would naturally require the expenditure of a very large capital sum of money. The electrical power thus obtained will be utilised by the Government in the manufacture of chemical manure, in a similar manner to the processes adopted in Norway.

The Shipbuilding Ballot.—There is every prospect of a national shipyard strike, judging from the results of the ballot returns. These show that the strike majority in the large unions is now so heavy that the figures of all the other unions put together will be powerless to prevent a strike majority when the votes are pooled. Even more ominous than this news is the information that the metal-working trades, which, with the exception of the boilermakers and blacksmiths, were standing aloof from the agitation, are now falling into line, and negotiations will be opened up with a view to promoting joint action between all the unions concerned in the shipbuilding industry. The metal working section of the industry will concentrate on the eight hours day demand rather than on wages. The only hopeful feature of the situation is that the combined unions will ask the employers for another conference before putting the strike mandate into operation.

Cost of Producing Steel and Pig Iron in the United States.—Mr. J. A. Farrell, president of the United States Steel Corporation, giving evidence in the suit by the Government for the dissolution of the corporation, stated that the cost of steel production in America was greater than in European countries. The wages paid abroad were 37 to 38 per cent. less than those paid in America, while freight rates were lower and shipping facilities better. Mr. Farrell stated that pig iron could be manufactured in India and laid down in Calcutta at 23s. 4d. per ton. There was now under way from Calcutta to San Francisco the first cargo of Indian pig iron ever brought into the United States. The freight rate was 22s. 11d. per ton, and under the new tariff the duty would be 5½d. per ton. Thus this pig iron could be laid down in San Francisco at a cost of about 47s. 11d. per ton, and Chinese pig iron could be similarly supplied at 44s. 11d. per ton, while the present market price of pig iron on the Pacific coast was 89s. 7d.

The Trade of India.—A return has recently been issued from the India Office showing the total exports from India to each of

the principal countries of the world, and the total imports from the same places for the year 1911 12. The total exports for the year amounted to £158,908,091, of which £70,604,753 went to the United Kingdom and British possessions, and £88,303,338 to foreign countries. The United Kingdom is by far the best customer of India, the exports to this country totalling £42,331,706, while those to Germany, the next best customer, were of the total value of only £15,105,656. Japan is the third best customer, the exports to that country amounting to £11,163,264; and the United States are fourth with exports to the value of £10,444,208. The total imports for 1911 12 amounted to £131,684,190. By far the greater proportion of the imports came from the United Kingdom and British possessions, the total being £95,978,106, and only £35,706,084 came from foreign countries. The share of the United Kingdom in the imports was £79,770,861.

Walsall Electricity Undertaking.—The report of Mr. E. M. Lacey, who was called in by Walsall Town Council to report upon their electricity undertaking, has just been issued. In a summary Mr. Lacey expressed regret that he had been unable to frame a scheme to afford a reasonable prospect of the existing power station and system being so far modernised and brought up to date as to secure economical production. He was satisfied that the only way to make the electricity undertaking a commercial success, and to provide power users with a cheap and efficient supply of electricity, would be to forthwith initiate and push forward a scheme for a new and efficient power station and system of supply. The only way to provide for the future demand in Walsall would be to erect a power station of some 3,000 kw. capacity. An estimate of the cost fixes the total expenditure which would be involved at about £38,000, but it is pointed out that, in addition, the Corporation would have to "scrap" the existing direct current plant, which would represent writing off capital to the amount of over £34,000. The report will come before the Council at their next meeting.

Reinforced Concrete in Mines.—In the course of a paper read before the Concrete Institute, Prof. S. M. Dixon said that reinforced concrete was at present very little employed under ground, but its use was growing; it was becoming general for pit-head works, such as bunkers and hoppers, and in a few mines in Great Britain it was used on a large scale below ground, some of the principal pits being Baggeridge, near Dudley; Sneyd, near Stoke-on-Trent; and Tunnel Pit, Haunchford, near Nuneaton. The ingenious methods of using timber had been so successful in the past that it might need a good deal of argument to convince the mining engineer generally that even in some cases a comparatively new material like reinforced concrete might be an economic and useful substitute. To the miner the use of timber was now instinctive, and the many changes in his work, necessitated by the adoption of concrete and reinforced concrete, seemed irksome to the greatest degree. The engineer was also to blame in some cases because, without studying the special conditions, he merely aimed at substituting one material for another, which, owing to years of experience, was being used in the forms to which it was most adapted.

A New Design of Testing Machine for Metals.—A demonstration was given on Friday last week in the laboratories of Messrs. Jonas and Colver, Ltd., Sheffield, on the possibility of showing in cinematograph form the crystalline changes that take place during the pulling of a test piece in the testing machine. The testing machine used has been designed and patented by Mr. B. W. Winder, M.I.Mech.E., and consists of a specially constructed machine, to which a microscope is fixed, connected with a camera, so that not only can the whole of the changes that take place be noted, but photographs can be taken at any time during the process. The microscope, which is a specially constructed one, however, can easily be affixed to any ordinary testing machine. The machine is worked hydraulically, the readings being taken on a pressure gauge. The hydraulic power is derived from a new system of accumulator worked by a hand pump. The whole apparatus, including the pump, testing machine, and accumulator, are all on a small bench, 6ft. by 3ft., and although the machine itself is only a little over 1ft. long, a test piece requiring 25 tons to rupture can be broken with the greatest ease.

A Large Clyde-built Dredger.—The dredger "Balari," which was launched on the 22nd inst. by Messrs. William Simons & Co., Renfrew, to the order of the Commissioners for the port of Calcutta, is the largest dredger yet built on the Clyde. The dredger, which is 333ft. in length, 54ft. 6in. in breadth, and 22ft. 3in. in depth, has a hopper capacity of 71,600 cub. ft., and has been specially designed for the unique character of the dredging which has to be done on the Hooghly. The propelling and pumping engines are in two independent compartments. The propelling power is supplied by two sets of triple-expansion surface condensing engines. Steam is generated by four large single-ended horizontal multitubular boilers constructed for a working pressure of 180lbs. The pumping outfit, placed forward of the hopper in an independent engine-room, consists of one set of triple-expansion engines, with independent condensing plant and circulating pumps, complete with all modern fittings. The pump engines are coupled direct to a centrifugal sand pump specially designed to raise and discharge about 5,000 tons of sand and silt per hour. The pump is connected to a suction pipe placed in a well at the fore end of the vessel. The suction end of this pipe is fitted with a specially designed nozzle to suit the character of the material to be dredged. The suction pipe is controlled by a steam winch placed on the deck. The discharge pipe from the sand pump is carried aft of the hopper.

Trade Circulars and Catalogues.—We have received from Messrs. David Bridge & Co., Castleton, a copy of a new catalogue they have issued of friction clutches, mill gearing, and haulages. A special feature of this catalogue is the number of small photo illustrations of various clutch and gearing installations they have constructed, and which should prove of great assistance to those who have to deal with the arrangement of difficult drives. The firm state they will be pleased to forward a copy of the catalogue to any address on application. From Messrs. Siemens Bros., 38 and 39, Upper Thames Street, London, E.C., we have received a copy of two new price lists of electrical heating apparatus.

Messrs. Evershed & Vignoles, Ltd., Acton Lane Works, Chiswick, London, W., send us a copy of some recently published lists dealing with Evershed's portable ammeters and voltmeters of the indicating type. The combined ammeter and voltmeter sets are interesting, as they enable the engineer to cover a very wide range of measurements with one instrument. Also a copy of the price list of their "Megger" testing sets, which includes one for use in cases where prolonged testing is necessary, and a new high range insulation testing set for values of resistance up to 5,000 megohms.—Mr. O. N. Beck, 11, Queen Victoria Street, sends a circular of a rather ingenious four-way valve termed the "Triplex." The valve has four valve seats arranged in pairs with a valve interposed and so connected to the inlet and outlet junctions as to enable three alternative connections and two alternative closings to be effected. The steam admitted can therefore be diverted in several directions, and one or the other of the passages from the junctions can be closed. The valve particularly lends itself to boiler and superheating arrangements where one or more communications require to be combined or cut out.—The London Balata and Raw Hide Manufacturing Company, Willesden Junction, send us price lists and particulars of their various specialities.—The Car and General Insurance Corporation send us an interesting illustrated booklet showing that the motor vehicle is by no means the modern invention it is usually supposed to be. As a matter of fact it dates back as far as 1770. There is no doubt that the opposition of the railways in the early "thirties" prevented the development of the railless motor vehicle in this country for over 60 years, that is, until the passing of the "Locomotives on Highways Act" in 1896, called at the time the "Emancipation Bill," because it removed the legal requirement that a man should walk in front of every motor car on the highways waving a red flag. The company intimate they will be pleased to forward a copy of the booklet to any one on application.

METAL QUOTATIONS.

TUESDAY, MAY 27TH.

Aluminium ingot		95/- per cwt.
„ wire, according to sizes, &c.	from	112/- „
„ sheets „ „	„	126/- „
Antimony	£31/-/- to	£33/-/- per ton.
Brass, rolled		8½d. per lb.
„ tubes (brazed)		$10\frac{3}{8}$d. „
„ „ (solid drawn)		9½d. „
„ „ wire		$8\frac{3}{8}$d. „
Copper, Standard		£68/10/- per ton.
Iron, Cleveland		70/6 „
„ Scotch		76/6 „
Lead, English		£20/5/- „
„ Foreign (soft)		£20/-/- „
Mica (in original cases), small		6d. to 3/- per lb.
„ „ „ medium		3/6 to 6/- „
„ „ „ large		7/6 to 11/- „
Quicksilver		£7/10/- per bottle.
Silver		$27\frac{13}{16}$d. per oz.
Spelter		£23/5/- per ton
Tin, block		£221/10/- „
Tin plates		14/1½ „
Zinc sheets (Silesian)		£28/10/- „
„ (Stettin; Vieille Montagne)		£28/12/6 „

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Ferrules for the ends of boiler tubes. Pecinka. 2776.
Manufacture of bar and tube shaped articles from molten metal. Pehrson. 3221.
Multiple spindle drilling machines. Smith. 5452.
Thrust bearings. Parsons. 8266.
Construction of ships. Mackintosh & Mowatt. 10201.
Means for rendering navigable vessels unsinkable. Kemp. 10335.
Railway and tramway systems. Hayward. 10417.
Clutching and braking devices for high speed machines. Lee. 10426.
Bayonet joint unions for tubes. Berryman. 10440.
Propelling mechanism for aerial machines. Boughton. 10556.
Carburetters for internal-combustion engines. Claudel. 10638.
Valves for internal combustion engines. Brodie & Brodie. 10905.
Portable apparatus for lifting or discharging liquids. J. Stone and Co., and Parsons. 10960.
Construction of ships. Scott. 10990.
Deep boring rock drills. Harker & Allcock. 11174.
Motor. Meek & Derry. 11243.
Air gas plant. Archibald Bruce & Co., and Bruce. 11291.
Grates and firebars for boiler furnaces. Carnegie & Milliken. 11318.
Lubricating systems. Maranville. 11321.
Process of burning fuel in furnaces. Grieve. 12541.
Valve operating gear. Russell. 12942.
Rock drills. Rud Meyer Akt. Ges. fur Maschinen und Bergbau 13246.
Reversing gear for four-stroke cycle internal-combustion engines. Eisenhuth. 13269.
Valve mechanism for internal combustion engines. Garnier. 13451.
Testing of engines. Electric and Ordnance Accessories Company, and Etchells. 13982.
Steam traps. Maurer. 14259.
Tools for scaling condenser tubes. Gilman & Clements. 14294.
Calcining or roasting furnaces. Prager. 14464.
Steam traps. Ogden. 15748.
Vaporisers of internal-combustion engines. Crossley & Webb. 15814.
Variable speed gearing. Lake. 15945.
Vice. S. Allcock & Co., and Powell. 16398.
Propellers for aerial machines and marine vessels. Clarkson. 16402
Internal-combustion engines. Hamilton. 16912.
Water circulator for boilers. Mackenzie. 17047.
Rotary tool holders. Pieper. 17268.
Controlling gear for winding and hauling engines. Melling. 17888.
Starters for explosion engines. Kelley. 18069.
Preparation for rendering coal dust non-explosive. Arnott and Goodall. 18801.
India-rubber diaphragms for pressure controlling valves. Auld. 19220.
Multi-cylinder internal-combustion engines with rotary valve mechanism. Schaar. 19342.
Semi-automatic cut-off valves. Thomas & Jeffries. 19420.
Mechanical stokers. Wood. 19660.
Radiator systems for the cooling of motor cylinders. Daimler Moteren Ges. 19753.
Over-winding and speed controlling gear for winding and haulage engines. Bennett. 19833.
Reducing valves. Dewrance. 20008.
Variable mould for casting metals. Coleman. 20246.
Automatic controller for winding engines. Harbottle. 20310.
Oil-gas generators. Kuenzel. 20709.
Controlling mechanisms for preventing overwinding or running at excessive speeds in winding gears. Black. 20752.
Chain grates for furnaces. Pregardien & Konrad. 21541.
Machine for welding tubes. Spranger. 21587.
Valve gear for internal-combustion engines. Prestwich. 22135.
Apparatus for welding the seams of tubes. Vogel. 22315.
Cylindrical face milling tools. Schmalzried. 22479.
Means for economising steam and regulating the pressure and temperature in steam-heating plants. Kohler. 23263.
Chucks for rock drills. Vaught. 24120.
Die stocks. Hart. 24610.
Devices for ensuring a noiseless running of explosion motors. Tecklenburg. 24644.
Compressors for oil engines. Fornaca. 24673.
Fixing of water jackets on to the cylinders of revolving cylinder engines. Windhoff. 25872.
Starting devices for internal-combustion engines. Crouse and Eidson. 25889.
Speed-regulating devices. Peterson. 25901.
Aeroplanes. Jirasek. 25961.
Tilting arrangement for metallurgical furnaces. Jössingfjord Manufacturing Company A/S. 26166.
Internal combustion engines having slide valves. Laycock. 26565.
Air pumps. Mackintosh. 27532.
Steam generators. Robinson. 27655.
Calorifers. Miles. 27800.
Nut locking devices. Church. 27804.
Ratchet spanners. Earl. 28455.
Steam separating and purifying apparatus. Caird. 29166.
Cooling rotary cylinder internal combustion engines. Windhoff. 29691.

1913.

Furnaces. James. 277.
Apparatus for controlling motion from a distance. Siemens Schuckertwerke Ges. 1047.
Expanding screw sockets. Wagner. 2420.
Railway signalling or indicating systems. Stuart. 3588.
Portable railway crane. De Bruyne & Schrader. 5012.

ELECTRICAL, 1912.

Electric railway systems. Stuart. 2957.
Electric lamp holders. Hale. 7552.
Regulation of the frequency produced by polyphase induction generators. Siemens-Schuckertwerke Ges. 8070.
Electric resistances and heaters. Gualtierotti. 10657.
Establishing electrical communication between ships and the shore. Possolo. 10701.
Electric incandescent lamps and lamp-holders. J. Stone & Co., and Myers. 10959.
Electric switches. Perl. 11051.
Electric arc welding. Strohmenger. 11079.
Graded service automatic telephone system. Baron. 11261.
Electrical measuring apparatus of the moving coil type. Apthorpe and Cambridge Scientific Instrument Company. 11279.
Remote control for electrically operated apparatus. Thompson. 11537.
Arrangement of receiving stations for wireless telegraphy. Zaharia and Rothlander. 12144.
The production of alternating currents of high frequency. Sefton-Jones. 14390.
Means for obtaining two separate and opposite drives from a single electric motor. Holmes & Kemp Welch. 14560.
Holders for electric incandescent lamps. Wankmuller. 14750.
Leading-in conductors for sealing into electrical apparatus. British Thomson Houston Company. 15342.
Selector switching device for automatic telephone systems. Telephon Apparat Fabrik E. Zwietusch & Co. Ges. 16151.
Electrolytes for use in electro-metallurgy. Dekker. 17836.
Incandescent electric lamps. Joly. 20361.
Dynamos. Polkey, and George Polkey, Ltd. 22500.
Electric electrode furnaces. Jössingfjord Manufacturing Company A/S. 26165.
Electric incandescent lamps. Sidon. 27813.
Non-shunt electric arc lamps. Rogers & Rowe. 28627.

1913.

Electric furnaces for fixing nitrogen from the air. Harker and Scott. 866.
Field magnets for dynamos. Siemens Schuckertwerke Ges. 3627.
Electric regulating liquid resistances. Boutard. 3855.
Transmitters for use in wireless telegraphy. Sahulka. 6479.

Specifications for Babbitt Metals.—A sub-committee of the American Society for Testing Materials has been appointed to evolve standard specifications for Babbitt metals. There are at present a large number of Babbitt metal mixtures in use, the majority of which differ only slightly in the ingredients. It is proposed to reduce these to five, a number which the committee think will be ample for every class of work. The following table gives the composition of the series which it is believed cover the range for all requirements:—

No.	Tin.	Antimony.	Copper.	Lead.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1	83·33	8·33	8·33	—
2	89·00	7·00	4·00	—
3	50·00	15·00	2·00	33·00
4	5·00	15·00	—	80·00
5	—	12·00	—	90·00

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WILLIAM H. FOWLER
Wh. Sc., M.Inst.C.E.

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Cheques and Postal Orders should be made payable to the Scientific Publishing Company, and forwarded to our Manchester Office, 53, New Bailey Street.

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The Relative Merits of Acid and Basic Steel.

THE generally-accepted opinion amongst engineers is that acid steel is much better than basic steel for all engineering structures in which reliability and safety are factors of prime importance, and a reference to failures in practice with the latter material would no doubt furnish strong evidence to support this opinion; but while this should carry due weight, it ought not to unduly exalt the merits of the one material or depreciate those of the other. "Give a dog a bad name and hang it" is a trite adage of wide application, and we cannot avoid thinking that basic steel has to some extent suffered in this way, though, of course, a user would say, "Once bitten, twice shy." Certainly the views of engineers, which are of course mainly confined to the practical application of steel, do not altogether accord with those of steel makers who have, it must be conceded, a wider experience of the factors which go to make either a good or bad product with either class of material. In the manufacture of acid steel the maker is obliged by the process to exercise a degree of care in selecting his stock which is not necessary in the basic process, and to this extent a degree of compulsion is exerted over the quality of the final product, and it is contended that if the same precautions were exercised in the choice of stock and control of manufacture the basic would not fall short of the acid steel when measured by the usual chemical and physical tests.

Both processes have their points of superiority and inferiority. With acid steel the factors which may lead to inferiority are high phosphorus, high sulphur, oxide of iron—which, on account of the slow reaction of the bath, has to be added to hasten the removal of carbon and other elements—manganese, which burns out completely so that sulphur has to be neutralised by the ferro-manganese almost at the last moment before tapping, while silicon is usually present in such quantity that not enough can be added at the finish to have a good deoxidising effect on the metal. With basic steel occluded slag is very likely to be present in larger quantity

than in acid steel, as also is oxide of iron, which has a greater tendency to form on account of the basicity of the slag, although partly eliminated by the manganese which is always present. On the other hand, the factors which may lead to superiority are in the case of acid steel, first, that oxide of iron is not so likely to form, and secondly, that a small amount of slag is necessary in the bath and there is thus less probability of its getting into the steel. Against this we have the fact that with basic steel the phosphorus and sulphur contents are low, while manganese is always present and thus has plenty of time to react with the sulphur, while silicon burns out and a large amount may be added in the ladle to act as a deoxidiser. A consideration of these facts shows there are two sides to the question of relative merits if we exclude the compulsory selection of stock imposed on the maker of acid steel, and it is not surprising differences of opinion should exist even amongst metallurgists. A good defence of basic steel can certainly be made, as was pertinently shown by Mr. W. H. Keen* in a discussion of the matter in "The Iron Age" some time ago.

Engineers rely largely for their opinions of the two steels on the results of tensile tests, but experience has shown that such tests alone are inadequate for a sound judgment. Percentage of elongation, reduction of area, resistance to shock, as well as chemical and microscopical tests have all to be taken into account in forming a judgment, while it has to be borne in mind that even with similar treatment samples from the same heat will occasionally give discordant results. Mr. Keen quotes one case where two tests of samples from a 3ft. length of a 1in. round bar tested at the United States Bureau of Standards showed a difference of over 7,000lbs. in the tensile strength. The more, in fact, one knows of steel the more difficult it seems to devise any single figure which measures relative merits. Several formulæ have been proposed, based on a combination of tenacity and elongation, but while none can be regarded as quite satisfactory, Mr. Keen states that the following formula adopted by his company sometimes proved a useful guide.

$$M = \frac{T\,(E + 20)}{100{,}000}$$

where M = figure of merit, T = tenacity in pounds per square inch, and E = percentage of elongation.

It is well known that it is possible by heat treatment to reduce the elongation and simultaneously improve the tenacity and elastic limit or vice versâ, and the chief value of such a merit formula is in estimating within about what limits it is possible to vary these conditions on any one steel and in showing the relation between two bars irrespective of differences in strain and stress. This is strikingly shown by a table of tests taken from Howe's "Metallurgy of Steel," in which the author gives the usual upper and lower tensile strengths for any given elongation, with the corresponding figures of merit. The latter exhibit a remarkable uniformity for the upper limit and also for the lower limit, and suggest the possibility of meeting a specification by heat treatment with any given steel of which the tensile properties are already known. This merit formula, it will be observed, only correlates tenacity and elongation. There seems as yet no very exact way of correlating elongation with reduction of area, though in general for carbon steels it may be noted the percentage reduction is about twice the percentage elongation, while with alloy steels the tendency is to increase this ratio to nearly three times. The ratio, however, in either case is far from uniform, and various conditions of manufacture influence the ratio. Generally a forged bar gives a greater reduction of area than a casting, and the reduction is also greater with the refinement of the grain by heat treatment. The elastic limit is undoubtedly an important factor in materials subject to vibration, though a measure of this alone seems of no great assistance in determining quality, since it varies a good deal with different heat treatments. For example, by water annealing it is possible to increase elongation materially, whereas annealing by heat followed by slow cooling invariably reduces it, and it is of course greatly increased by hardening processes.

* Head of the research department, Washington Steel and Ordnance Company.

THE NEW RESERVOIRS AT CHINGFORD.

On Saturday, May 24th, a large party assembled at the new Chingford Reservoirs and Pumping Station of the Metropolitan Water Board on the occasion of a combined visit of three societies, the Institute of Marine Engineers, the Junior Institution of Engineers, and the Association of Engineers in Charge. The chief objects of interest were the five large Humphrey pumps on the internal-combustion principle, the first of their kind which have been recently installed, and the visitors were favoured with the presence of Mr. H. A. Humphrey, the designer of the pumps, who, in the course of the afternoon, gave a brief description of them to a large audience in the pump house. The whole series of pumps will only be required to work when there is sufficient surplus water in the River Lea available, and on the occasion of the visit only one of the pumps was shown at work. The combined capacity of the pumps is 180 million gallons per day, four of them having a capacity of 40 million gallons per day each, and one of 20 million gallons. The type of pump used at Chingford is designed to work advantageously with a low lift, the lift in this instance being about 25ft. to 30ft. The pumps work on the 4-cycle principle. On the mixture of gas and air being exploded in the combustion chamber, the column of water in the pipe is forced along, with the result that the air is expanded and the pressure falls to below that of the atmosphere, and a further supply of water is automatically admitted to the pump. The exhaust gases are driven out on the return stroke. A second outstroke follows, in which a fresh charge is admitted and the cycle is completed with a return stroke which compresses and fires this charge. The cylinders of the larger pumps are 7ft. diam. and develop 250 h.p. to 350 h.p. The explosion chamber heads are composed of cast steel; below these are the water suction valve boxes, connected by a bend and a 6ft. pipe to vertical steel towers in an adjoining building. From these water towers 4ft. pipes convey the water to the reservoir, into which it flows in a steady continuous stream over a granite terrace. The water towers receive 15 to 20 tons at a time from each pipe at each explosion, and the rise and fall of water in the towers enables the intermittent delivery to be converted to a continuous delivery. The enormous reservoir, which has a capacity of 3,000 million gallons of water, and an area of 416 acres, impressed the visitors with its magnitude.

A cordial vote of thanks was accorded to Mr. Humphrey, on the proposal of Mr. W. A. Tookey (Junior Institution of Engineers). The thanks of the party were also accorded to Mr. W. E. Bryan, M.Inst.C.E., chief engineer to the board, through whose courtesy the visit was arranged, and to Mr. Deveral, the resident engineer, on the proposal of Mr. A. H. Mather (Institute of Marine Engineers), seconded by Mr. A. E. Penn (Association of Engineers in Charge).

BOARD OF TRADE REGULATIONS FOR OVERHEAD LINES.

The following regulations have been issued for pressures exceeding medium-pressure continuous current and low-pressure alternating current:—

Supply.—1. The supply will be transmitted at a minimum pressure of — volts.

Conductors.—2. The conductors will be of hard-drawn copper wire or aluminium.

3. Hard-drawn copper wire conductors will have a breaking load of not less than 24 tons per square inch, and on breaking the

elongation will not be less than 2 per cent. in a length of 10in. Aluminium conductors will have a breaking load of not less than 12 tons per square inch, and on breaking the elongation will not be less than 3 per cent. in a length of 10in.

4. The minimum sag of the conductor will be regulated to give a stress due to its weight and to wind (but excluding its elasticity) of not more than one-fifth of the breaking load, at a temperature of 22° Fah. Wind pressure will be taken at 25lbs. per square foot, and the effective area of the conductor will be taken as 0·6 of the diameter multiplied into the length.

5. The minimum height of any part of any conductor from the ground will not be less than 20ft., except with the consent of the Board of Trade.

6. Conductors will not cross any building other than a sub-station or be accessible to any person from any building or tree without the use of a ladder or other special appliance. When the conductors are so placed that a tree, if uprooted, could come in contact with a conductor, an earth cradle enclosing them, or some other precaution approved by the Board of Trade, will be provided to prevent all danger of any shock.

7. Conductors will not be carried by the undertakers across the premises of a consumer, except with the consent of the Board of Trade and subject to such conditions as the Board may prescribe.

Poles.—8. The conductors will be carried on poles, either (*a*) wooden poles, or (*b*) poles or structures of iron or steel, hereinafter called steel poles.

9. Each pole will be clearly and permanently marked with a number.

10. Danger notices will be fixed on at least one pole in five and on each pole at the crossing of a road.

11. Provision will be made to prevent climbing by barbed wire being coiled round the pole, in one or more coils of an aggregate length not less than 2ft., the lowest coil being at least 8ft. from the ground.

12. Where guys or stays are used they will be securely anchored and earthed.

13. A continuous earth wire will be carried from pole to pole, and will be well connected to substantial earth-plates at intervals of not more than five spans; or the ironwork on each pole will be connected to a substantial earth-plate.

Wooden Poles.—14. The poles will be sound winter-felled red fir, free from large knots or other defects, with the natural butt, and will be well injected with creosote, or they will be of a description approved by the Board of Trade.

15. Single poles, or A poles, will be used for the ordinary run of the line. Stouter poles, H poles, or built up or strutted poles, provided if necessary with stays, will be used for terminals, for intermediate anchor poles, for important differences of span, and for corner poles where there is considerable change of direction. Ordinary poles provided with stays will be used where the direction makes a small change.

16. Poles of ordinary lengths, unless in rock foundation, will be set in the ground to a depth of 6ft. The earth will be well punned into the holes. Where necessary, they will be set in concrete.

17. The factor of safety for the poles will be calculated at 10, for a wind pressure of 25lbs. per square foot; the effective area of a round pole being taken at 0·6 of the mean diameter of the exposed part into the length of that part.

Steel Poles.—18. Poles of tubular type will be painted with oil paint not less than once every five years, and poles of the lattice type not less than once in every three years.

19. Each pole will be set in concrete.

20. The concrete below the pole will be dropped on to a substantial cast-iron earth plate bonded to the pole by a wire or rod.

21. The factor of safety for the poles will be not less than 6, taking the maximum wind pressure at 25lbs. per square foot. In the case of lattice poles, the pressure on the lee side will be taken as one-half of the pressure on the windward side.

Arms.—22. The conductors will be carried on insulators mounted singly or in pairs on steel channel arms, or singly upon iron brackets fastened to the poles; or if wooden arms are used, an earthing strip or stout wire will be fastened on the upper side of each arm.

Road Crossings.—23. Where the line crosses over a public road canal, or railway, the angle between the line and the direction of the road, canal, or railway at the place of crossing will not be less than 60°, and the height of the line not less than 25ft.

24. Where the line crosses over a public road canal or railway or runs parallel to it at a distance less than one and a half times the height of the highest wire from the ground it will be erected in a manner approved by the Board of Trade.

Where for the protection of his electric lines or works the Postmaster-General makes requirements, which, in addition to protecting those lines or works, afford ample provision for securing the safety of the public, further protection need not be provided.

25. Provision will be made by earthing brackets, or wires, or other device, to ensure that in the event of a failure of a conductor or of a pole, the line will be put to earth.

General.—26. Galvanised iron wire used for stays, cradles, or other mechanical purposes; galvanised iron binding wire; arm bolts, nuts and washers; stay swivels; truss and brace rods and truss tie, tie, and brace bolts; stay rod tighteners; and test pieces, will conform with the British standard specification for such material (British standard specification of telegraph material) so far as that specification is applicable.

27. The work will be carried out so far as circumstances permit in accordance with the Post Office technical instructions for the construction of aerial lines.

28. Where the line crosses, or is in proximity to, any other wire or metal, precautions will be taken by the undertakers against the possibility of a conductor coming into contact with the other wire or metal or of the other wire or metal coming into contact with the line by breakage or otherwise.

29. Every line including its supports and all the structural parts and electrical appliances and devices belonging to or connected with the line, will be duly and efficiently supervised and maintained as regards both electrical and mechanical conditions.

30. Every line, including its supports, will be removed on ceasing to be used for the supply of energy, unless the Board of Trade are satisfied that it is to be again brought into use for such supply within a reasonable time.

Memorandum issued for the guidance of applicants for the consent of the Board of Trade to the placing of electric lines above ground.

Every application for the consent of the Board of Trade to the placing of electric lines above ground should be accompanied by the following particulars:—

1. Where the undertakers are a company, or a local authority supplying outside their own area, evidence of consent of the local authority for the district.

2. A statement showing commercial or other considerations why underground cables should not be used.

3. A brief description of the proposed system, including the working voltage; the kind of wire whether copper or aluminium; whether solid or stranded; the total sectional area; tensile strength and elongation; average and maximum length of span; minimum height of wires from the ground; name or description of automatic protective device, if any.

4. A statement whether the supply is to form (1) an extension of an existing system of underground cables, or (2) of an existing traction system, or (3) an independent system.

5. An ordnance map on a scale of 6in. to the mile, showing the proposed route of the overhead lines and any existing overhead lines. The sheets of these maps must not be fastened together.

6. In the case of high and extra high pressure, plans of construction of poles, &c., on a scale of about 1in. to the foot, or a reference to previously deposited plans where these are identical with the proposed work.

NOTES.—Codes of Regulations have been made (1) for overhead lines for low-pressure and medium-pressure continuous-current supply, and for low-pressure alternating-current supply; and (2) for pressure exceeding low or medium pressure continuous current and low-pressure alternating current. Regulations will be made for each case separately, following these codes unless special alterations are sanctioned.

Attention is called to the necessity for obtaining the approval by the Postmaster-General of plans and works under Sec. 14 of the Schedule to the Electric Lighting (Clauses) Act, 1899.

Board of Trade, *May*, 1913.

QUADRUPLE-SCREW TURBINE-DRIVEN HAMBURG-AMERICA LINER "IMPERATOR."

The building and fitting-up of this great liner, which was launched on May 23rd of last year by the Emperor William II., and which will shortly start on her first journey across the Atlantic, is an achievement of which our German cousins are justly proud. Built at the Vulcan Works, Hamburg, for the Hamburg-America Line, the "Imperator" is the largest liner afloat, and embodies everything that recent experience can suggest, as regards the construction of the hull with a view of safeguarding the lives and property of the passengers and crew, and as regards the machinery with a view of ensuring a maximum speed combined with a maximum of comfort. The vessel is likewise fitted up with royal munificence, making the name which the German Emperor bestowed on it at the launching ceremony appear indeed a fitting one. A double compliment has, by-the-bye, been paid to us by placing the management of the wonderful independent restaurant into the hands of the Carlton Hotel Company, London, and by arranging the first smoking saloon of the "Imperator" in the style of an old Tudor interior, built and fitted up by W. E. Thornton Smith, London. With its heavily-profiled and carved beams in solid oak, its open stone fireplace, leather-covered oak chairs, and ornamentation of weapons and horns, this room will form a haven for the masculine portion of the passengers desirous of spending a few hours in artistic yet homely surroundings.

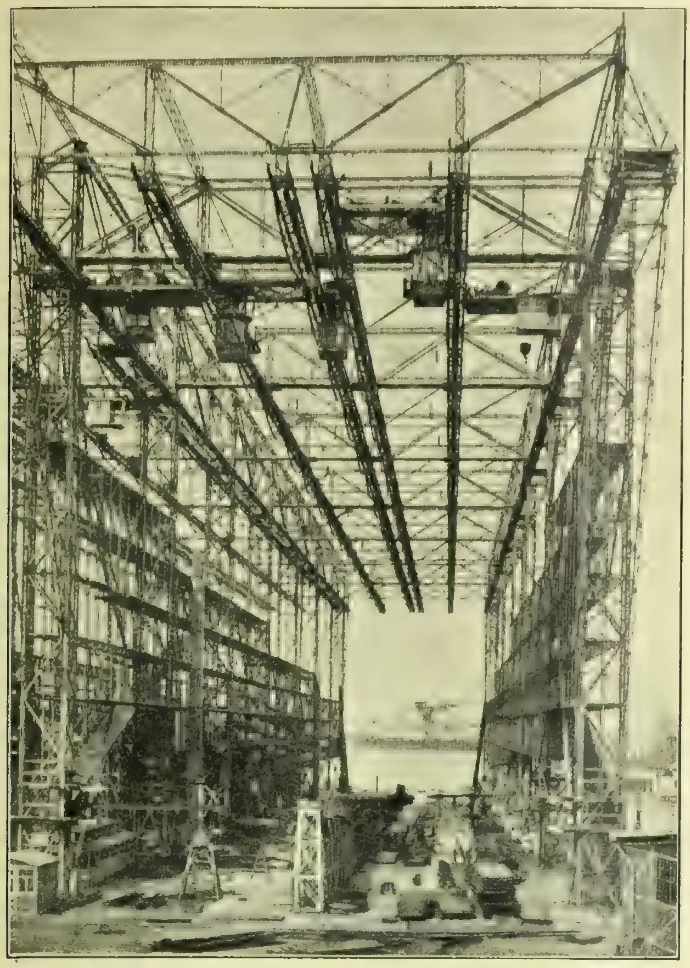
Quadruple-screw Turbine-driven Hamburg-America Liner "Imperator."
View showing the vessel on her first journey down the River Elbe on April 22nd, 1913.

The laying of the keel was commenced on June 18th, 1910, and in the spring of 1911 the erection of the side framing was started. She has a double bottom and a collision bulkhead extending up to the main deck. As an additional provision against collision, a double skin is provided in the fore portion of the ship, reaching from the collision bulkhead through the three loading spaces to the foremost boiler-room bulkhead to considerably above the water line. The after portion of the ship is provided with numerous longitudinal and cross bulkheads in the tunnels for the shafting and the engine-room. In the middle of the ship are arranged numerous coal bunkers and water-tight bulkheads extending far above the water line. In the case of a collision, therefore, the entrance of the water into the inner ship's body is either prevented entirely by the collision bulkhead, the double skin, or the coal bunkers, or, in the case of very serious damage, is restricted to the portions of the ship immediately concerned. The water-tight doors provided in the bulkhead can all be shut instantly from the captain's bridge by means of Dörr-type closing arrangements. As a reserve protection, mechanical closing arrangements are provided on the upper deck. The quantity of material used in the construction of the vessel was roughly about 26,000 tons of steel plates, angles, profile, and flat iron, &c.; 1,400 tons of rivets and screws; 600 tons cast and wrought iron of all shapes; 212,000 cub. ft. of different kinds of wood, &c.

The dimensions of the vessel are: Length over all, 906ft.; length at lowest water line (deep-loading line), 880ft.; breadth, 98ft.; depth from upper edge of keel to upper edge of beam of upper deck amidships, 63ft.; depth to side of boat deck, 100ft. 4in.; height of ship from point of loading mast to keel, about 246ft.; height of funnels above upper deck, 69ft., above water line, about 148ft.; diameter of funnels in the longitudinal axis, 29ft. 6in., in the lateral axis, 18ft. The loading capacity of the ship is 12,000 tons; displacement at full load, 57,000 tons; capacity, about 50,000 gross-register tons; and draught, 35ft. 6in. The launching weight of the vessel, including cradle, was about 27,000 tons; and weight of ship's body, excluding machinery, boilers, and load, about 33,800 tons. There are five steel decks running through the whole of the ship; one partial room deck in fore ship and after ship; and one further partial room deck in the fore ship. Above the first (upper) steel deck (main deck) there are a further four decks (bridge deck, lower promenade deck, upper promenade deck, and boat deck). The cabins can accommodate altogether 2,476 passengers, the crew numbering some 1,180.

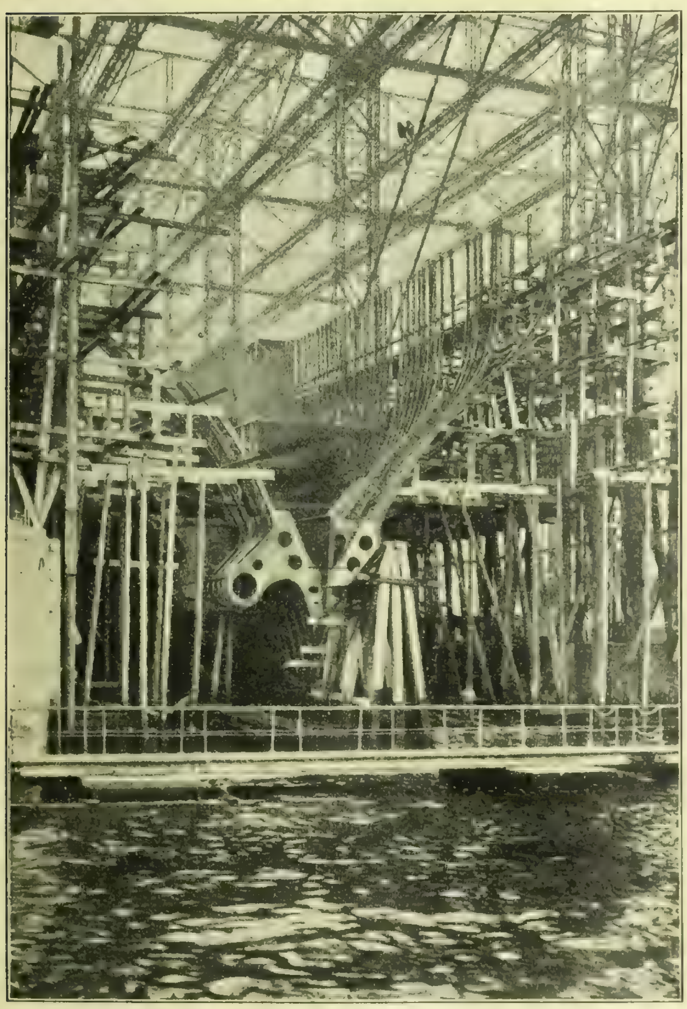
The ship is propelled by four 4-winged propellers of slightly over 16ft. 5in. diam., made of Turbadium bronze, making normally 185 revs. per minute. The propelling machinery is accommodated in three engine-rooms, the foremost one of which is 69ft. long, and the two others 95ft. long. The total forward effort amounts to 62,000 h.p. The backward effort of all astern turbines amounts to 35,000 h.p. The steam at "going ahead" passes first to a high-pressure turbine on one of the inner shafts, then an intermediate-pressure turbine on the other inner shaft, and then passes equally divided on to two low-pressure turbines on the outer shafts. Each separate shaft is available, however, by itself

QUADRUPLE-SCREW TURBINE-DRIVEN HAMBURG-AMERICA LINER "IMPERATOR."

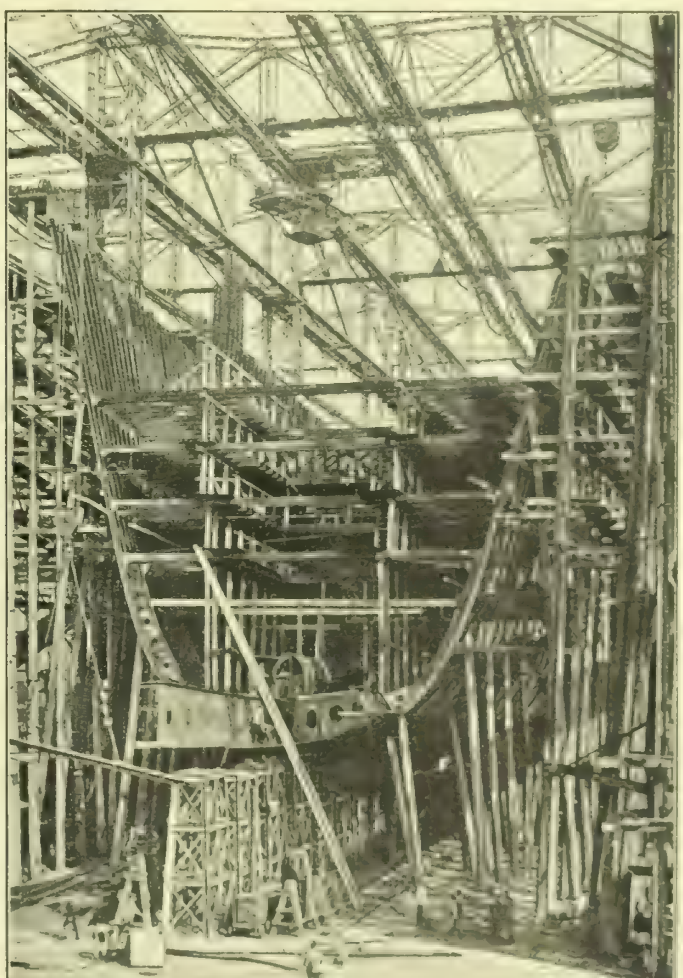


LAYING OF THE KEEL AT THE VULCAN WORKS, HAMBURG, AUGUST 1910.

VIEW AMIDSHIP, LOOKING AFT, SHOWING ONE ENGINE ROOM AND ONE BOILER-ROOM



STERN PART OF SHIP, WITH END FRAMING FOR SHAFT BEARINGS, SEPT., 1911.



THE FIVE LOWEST DECKS IN FORWARD POSITION, SEPTEMBER, 1911

for running or manœuvring. The astern turbines are subdivided into two equal high-pressure and low pressure turbines, the low pressure being again arranged on the outer shafts. The total turbine installation has 760,000 bronze blades, which, laid in a line, would have a length of about 125 miles. The thrust bearings, which have to take up the thrust of the propellers, have a surface of about 75 sq. ft. altogether. The exhaust steam is condensed in four condensers of pear-shaped section, each having a cooling surface of 16,150 sq. ft. Four centrifugal pumps of 4ft. 3in. diam., driven by two engines, supply the cooling water for the condensers. The water of condensation is emptied by four dual air pumps (Weir system) into two large tanks. Four double feed pumps draw the feed water from the tanks in the double bottom, and, in conjunction with four main feed pumps, deliver it into the boilers. economisers for heating the feed water, are provided. To supplement the feed-water heaters, three 2-step evaporators are provided, each of which can prepare 100 tons of feed water in 24 hours.

For harbour service two auxiliary condensers are fitted in the engine-room, served by two special auxiliary cooling water pumps, as well as two auxiliary air pumps. Four steam ballast pumps draw the ballast water from the tanks if the ship is to be loaded. Two drain pumps draw the water of condensation from the turbine casings, six oil pumps supply efficient lubrication to the turbine bearings, and two further pumps lubrication to the shaft bearings. The ventilation of the engine-rooms is effected by three fan ventilators, each driven by a steam engine. The boiler-room is ventilated by four similar ventilating engines.

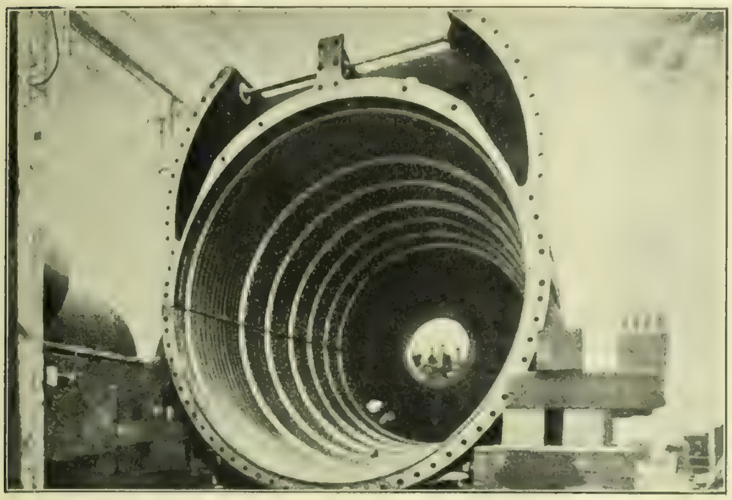
QUADRUPLE SCREW TURBINE-DRIVEN HAMBURG-AMERICA LINER "IMPERATOR."
The building of the vessel has progressed to the upper promenade deck View shows the wharf crane, the largest in the world, lifting rotor of a low-pressure forward turbine.

There are 46 single water-tube boilers arranged in four rooms, each 75ft. long and extending with their bunkers over the whole width of the ship. These rooms are separated by water-tight cross bulkheads. The necessary steam is generated at a pressure of 235lbs. on the inch. The total heating surface is 203,000 sq. ft., and the total grate area 3,760 sq. ft. The air required for the forced draught (Howden's system) is drawn by four fan blowers partly installed in the engine-room and partly in the boiler-room. Each of these blowers has a fan of 13ft. 9½in. diam. and forces the air through channels of 45 sq. ft. cross-section into the space under the grating of the furnaces. Four ash-ejector pumps with 6,356 cub. ft. capacity per hour, 16 ash ejectors, six ash hoists, and three ash-cooling valves are provided for removing the ashes from the furnaces over board. Four steam bilge pumps, each of 4,944 cub. ft. capacity per hour, continuously empty the bilges of the engine and boiler-rooms. Four feed-water purifiers, two oil separators, as well as two mixing feed-water heaters and two

The electric current is generated by five turbo-dynamos situated in the lateral back-board engine-room and one dynamo driven by a petrol engine situated on the boat deck well above the water line, so as to be available even in case of a breakdown of the general machinery. This latter dynamo serves all the passages, the most important working or administration points, especially on the boat deck. The first 5 dynamos have each a capacity of 2,000 amperes at 110 volts. The auxiliary dynamo has a capacity of 100 amperes, and serves, besides the auxiliary illumination, the entire command stations and the apparatus for wireless telegraphy. Besides the current for lighting, the dynamos also furnish the power for all motors, altogether 850 h.p. The wireless station is arranged on the boat deck, and comprises two reserve-antennæ and two receivers for long and short waves (news and salvage or life-saving service), available for a distance up to 1,500 sea miles.

The steering rudder, weighing about 90 tons, is suspended

by five hinges from the stern framing. The diameter of the rudder shaft in the stuffing-box is about 2ft. 6in. The rudder frame—a steel casting by Krupp, of Essen—is in two parts; it has a height of 57ft. 6in. and weighs 110 tons. Frahm's system of anti-rolling tanks are fitted amidships for damping the rolling movements of the ship and preventing sea-sickness.



TURBINE CASING WITH HOLE FOR SHAFT.

Besides natural ventilation artificial ventilation is provided in the living and social rooms by 80 Sirocco fans, each of 5,300 cub. ft. to 10,600 cub. ft. capacity per minute (total about 671,000 cub. ft.) coupled direct to electric motors. All the ventilating channels are conducted together into groups and terminate in air shafts which here and there project above deck and are covered by roofs.

In addition to four passenger lifts, which are worked electrically, there are provided 10 loading windlasses, each of 3 tons lifting capacity; three hauling winches on the back deck and after deck; two electrically-worked cranes for luggage, &c.; and four electrically-worked boat windlasses. The vessel is provided with the usual conveniences, including a swimming bath and gymnasiums.

THE ELECTRIFICATION OF THE STATE RAILWAY: THE PARIS SUBURBAN LINES.*

BY A. N. MAZEN.

Traffic of the State Railways System.—The State Railways system, formerly the Ouest lines, serves a very considerable portion of suburban Paris. The lines of this system, which end at three termini, namely, that of St. Lazare on the right bank, that of the Invalides and Montparnasse on the left bank, comprise at present a total length in this section of about 500 km. of single track. This total will be increased to 800 km. in a few years' time when the proposed loops and junctions will be finished and when the new line from Montparnasse to Chartres now in course of construction will be opened to traffic.

A huge traffic naturally corresponds with such a large development of track. From the point of view of the number of outward and inward travellers, the St. Lazare station is by far the most important, not only of the Paris but of European stations. Only Liverpool Street station in London is at all to be compared with it. This traffic movement, however, is far from stationary; it is always increasing, and statistics show that during the last 10 years it has grown by from 3 to 4 per cent. per year, while it would appear that if steam traction were retained, it would be doubled in about 25 years. In addition to its services, the State railway organisation has to suffice for its main-line service, and the importance of this traffic can easily be imagined when it is considered that the system, with its 9,000 km. of track, serves Normandy, Brittany, le Perche, Anjou, la Vendée, la Saintonge, and all the coast line from Tréport to Bordeaux.

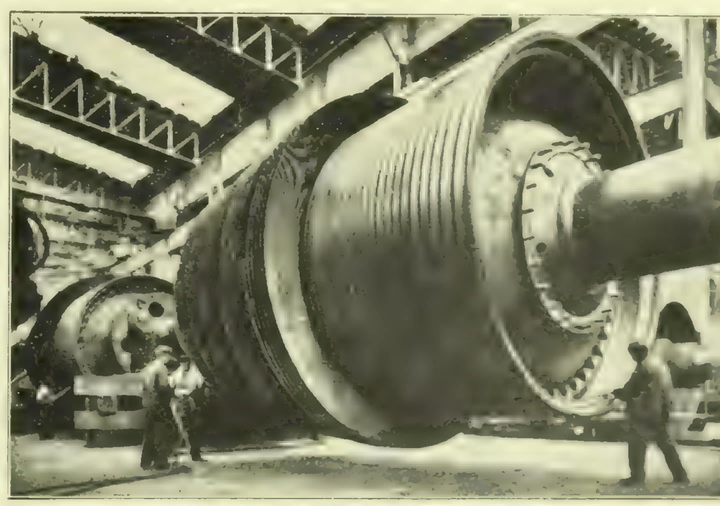
This fan-shaped system brings daily from the 10 principal extremities (Dieppe, Le Havre, Cherbourg, Granville, Brest, Saint-Nazaire, Nantes, Les Sables, La Rochelle, and Bordeaux) more than 80 train loads of passengers into the capital by the main lines.† If to these the number of suburban trains are added, a total of more than 820 train loads entering Paris daily is obtained, which, with the outward trains, amounts to a total of more than 1,640 trains (in and out) in the 24 hours, and as the day is made up of 1,440 minutes, this corresponds to more than a train per minute entering or leaving Paris.

The number of passengers who annually make use of the three State railway termini of Paris amounts to about 70 millions. Of this total the St. Lazare station alone accounts for about 60 millions; and the annual increase is of the order of 2 millions. One-third of the total annual number of suburban passengers use the stations contained within the area of Asnières, Colombes, La Garenne, and Courbevoie. This is of great importance in organising the traffic.

It is, of course, clear that such a traffic development can only have grown gradually, not only in the number of trains but also, thanks to modern steam locomotives, as to their weight. The permanent way and everything connected with it must be utilised to its maximum capacity, and, as regards the lines leaving Paris, a diagram has been drawn up dealing with the rush hours, and for certain suburban sections, the maximum authorised number of 24 vehicles per train. At present the service is only made possible by using coaches with roof seats, which, as can be imagined, increase the capacity of the trains, but could not be retained in a modern scheme.

At certain times the congestion has become so great that, especially on two of the three lines which alone entered St. Lazare before the recent addition of a fourth line, the traffic exceeds 200 trains either way per 24 hours, while on all the other systems the figure does not exceed 100 ordinary trains, with the exception of the tramway trains of the Nord Railway and the Orleans system, in the case of the electric trains from the Gare d'Orsay. The movement on these two systems reaches figures of 148 and 130 trains (both ways) respectively. What has been said regarding the permanent way obviously applies also to the rest of the installations, *i.e.*, the termini, stations, branches, &c. A similar situation will be remembered when in 1908 the Compagnie de l'Ouest sanctioned a proposal involving the electrification of the lines of St. Germain and Argenteuil.

Since the incorporation of the Ouest lines with the State system the Administration gave renewed attention to the question, and a full programme was drawn up. It is this programme, the carrying out of which is still in progress, that is going to be studied below. In order to deal with the question systematically it is proposed first of all to examine the actual situation under steam traction; to consider the remedies to be adopted, and to study the changes in organisation necessary for success.



TURBINE ROTOR PARTLY FITTED WITH BLADES [illegible]

Actual Position as Regards the Working of the State Railway Suburban System.—If the position as it actually stands at present is examined a little more closely it will first of all be seen that, leaving out of consideration the 218 and 213 trains passing each way to Versailles and St. Germain through the neck formed by the triple tunnel underneath Batignolles to enter St. Lazare, the number of trains passing through

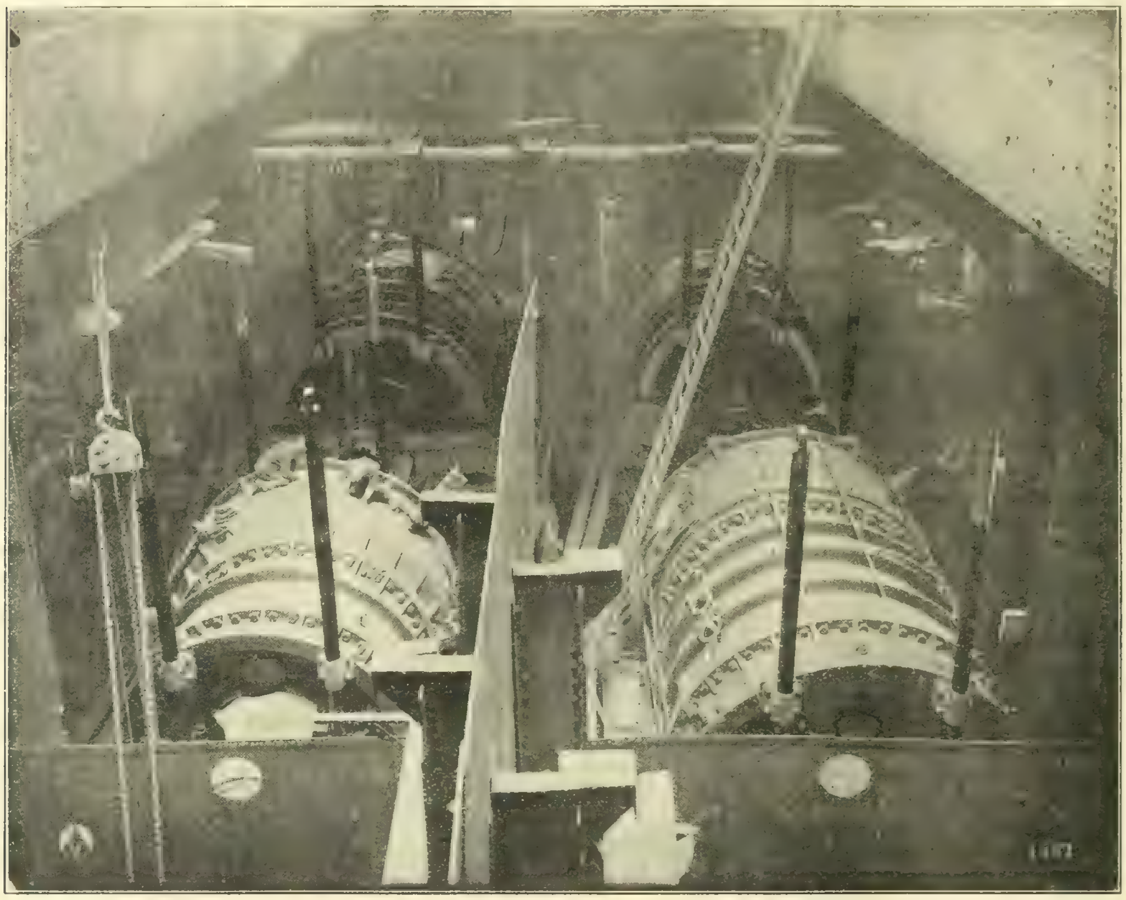
* Paper presented at the joint meeting of the Institution of Electrical Engineers and the Société Internationale des Electriciens, Paris, May 21st to 24th, 1913.

† All statistics refer to the years 1909, 1910, when the electrification scheme was got out

Asnières are 167 on the Versailles route and 197 on the St. Germain route. The other congested sections are:—

	Trains both Ways.
On the right bank:—	
Paris to l'Avenue Henri-Martin	150
Bécon to Puteaux	131
Asnières to La Garenne	106
Colombes to Argenteuil	103
On the left bank:—	
Invalides to Champ-de-Mars	139
Clamart to Porchefontaine	89
Porchefontaine to Versailles R.G.	67

It must be added that the most difficult sections to work are those in which trains having very different speeds (expresses, fast trains, local, and goods trains) are run on the same track, and in this connection the sections from St. Lazare to Asnières and from Clamart to Porchefontaine, the latter with a continuous up-grade of 6 mm. per metre, are noteworthy. During the busiest hours (6-30 to 7-30 p.m.) there are:



QUADRUPLE-SCREW TURBINE-DRIVEN HAMBURG-AMERICA LINER "IMPERATOR."
View in Engine Room, showing Turbines in course of erection (see p. 612).

	Trains both Ways.
Departing from Saint-Lazare:	
On Auteuil line	10
On Versailles line	11
On Saint-Germain line	11
Departing from Invalides:—	
On Porchefontaine line	4
Departing from Montparnasse:	
On Porchefontaine line	5

Such traffic congestion does not allow of a very good service for the different suburban sections. The number of trains each way per hour is about as follows for the different directions:—

	Trains.
Auteuil, Clamart	4
Champ de Mars, Moulineaux, Saint Germain, Argenteuil, and Mantes	2
Versailles R.D., Versailles R.G. (Montparnasse), La Garenne	1½
L'Etang-la-Ville, Passy, Conflans, Pontoise...	1

The speeds obtained are in almost every case insufficient. For the local trains a speed of 25 km. per hour (a speed scarcely greater than that of the Métropolitain, 20 km. per hour) can alone be assured; by the fast locals and fast trains from 35 km. to 45 km. per hour. Mantes, Poissy, and Versailles-Chantiers benefit, it must be remembered, by certain main-line fast trains.

The amount of rolling stock employed in the suburban service is very considerable, in spite of the comparatively small number of trains per hour. It comprises about 1,500 coaches and 200 locomotives, which represent, together with the necessary engine-sheds, workshops, and carriage-sheds, a total capital expenditure of more than 50 million francs. The magnitude of this stock is explained by the fact that on account of the difficulty of altering their composition they run practically as block trains, while as there are no carriage-sheds on the line, because they would have to be so large in view of the length of the trains, all stock is housed at the termini. Under these conditions the utilisation of the seating capacity does not exceed 18 to 20 per cent.

With such a method of working, the weight moved is obviously very great (1,500 million ton-kilometres per year). Of these figures the locomotives account for about 450 millions, that is, a little more than a quarter. Such very bad working conditions lead, necessarily, to heavy annual expenses, although the total distance run does not exceed 6,600,000 km. yearly. The final outcome from the financial point of view, is a large deficit, which will go on increasing unless stringent measures are taken for improving the suburban working. The only method of escaping from this situation appears to be a scheme for improving the service as a whole, while providing for a great increase in traffic.

Improvements to be Made.—The actual system of working is clearly inadequate, and it must be improved with as little delay as possible. The traffic is continually on the increase. During the rush hours overcrowded trains reach and leave Paris. If steam traction is to be retained, the number of trains must be increased. However, several reasons militate against any development in this quarter. First, the signalling systems of almost all the Paris stations are used to their fullest extent; second, the platforms of the Paris stations, and particularly those of St. Lazare and Montparnasse, are insufficient in number. This insufficiency applies particularly to steam haulage where long and complicated shunting movements are required to transfer the locomotive from the back to the front of the train. To these difficulties must be added those of watering and coaling the locomotives. At a terminus the necessity of making two, three, or four movements for every train coming in or going out blocks the exit roads and undoubtedly increases the chances of accident. To increase the capacity of the terminus and its platforms, it is absolutely necessary to decrease the number of these movements.

But how is this to be done? Obviously by preventing the transfer of the locomotive from the back to the front of the train, by equipping the train in such a manner that it can be driven either from the front or from the rear. Attempts have been made to solve this difficult problem for steam traction, but complications of every kind are met with. Some engineers have gone so far as to propose placing the locomotive

in the centre of the train, thus arriving at some kind of symmetry, but no arrangement of this sort has actually given complete satisfaction. With electric traction all requirements are satisfied. The system of multiple-unit control allows of all the electric motors driving the axles of the train, as is well known, to be worked from either end. With drivers cabins at the front and rear, a reversible train is obtained without any movement of the coaches. If a considerable proportion of the carriages of the train are made motor-cars, it is easy to split up the train into a number of separate motor driven sections, and this without any marshalling or manœuvring. This is a most suitable feature, as will be seen further on, and one which allows of proportioning the number of seats to the traffic requirements. This cannot be done economically with steam, since the locomotive, which forms a large proportion of the total weight of the train, must be in front. Further, by distributing the electric motors among the different carriages of the train a large adhesive weight is available allowing rapid acceleration, which permits of the trains getting away quickly from the platforms, increasing their capacity.

The Métropolitain and the Nord-Sud lines have brought out these conditions so clearly that it is unnecessary to labour the point. All these circumstances, combined with a sufficiently high schedule speed, will obviously allow of a considerable reduction being made in the time taken on the journey.

Before definitely giving up all idea of using steam, it might be well to look for a moment as to how it compares with electricity from the point of view of the capacity of the railway system line. The considerable experience obtained in the use of steam traction shows that it is useless to try to exceed a maximum of 10,000 to 12,000 passengers per hour with carriages without top seats, on a two-track line with frequent stops. In England, where certain systems use comparatively light trains hauled by heavy and powerful locomotives, 8,000 to 10,000 passengers per hour is barely reached. Here, thanks to lighter rolling stock, accelerations are obtained which, without being as great as are obtained with electric traction, are nevertheless considerably greater than in England; but, on the other hand, the cost of haulage is considerably increased.

By the side of these figures it is interesting to put figures relating to electric traction, it being remembered that with trains of 5 coaches carrying 500 passengers the Métropolitain is able to deal with an hourly total of 12,000 passengers. With carriages 3 m. instead of 2·40 m. wide, and 22 m. instead of 14 m. long, and assuming eight carriages per train, the enormous figure of 40,000 passengers per hour is reached, or, considering seats only (no standing), that of 20,000 passengers per hour.

On the occasion of the election of the President of the Republic it was found possible to bring 1,500 passengers to the Invalides from Versailles in six electric coaches of the above-mentioned type, which corresponds to an hourly total of 48,000. The journey was, moreover, done in 14 minutes. The conclusion is therefore arrived at that electric traction, with its rapid acceleration, allows of the time taken on the journey being so diminished as to double the capacity of the line. It moreover eliminates train movements and reduces the number of platforms at the termini necessary for a given service.

To obtain the preceding figures it must clearly be understood that each section of the line under consideration would be used only by suburban trains running at the same speed. This implies that trains of different speeds shall travel on separate tracks. In England, in the case of the London suburbs, the main line has been completely separated from the suburban traffic. The State railways have also approached this by considering the adopting of the zone system of working.

No section of a steam line can deal with more than 100 trains in each direction per day, whilst it is agreed that on electrified lines this figure may reach 350. This last figure is not at all startling when it is remembered that the Métropolitain and Nord-Sud give on certain sections the excellent service of more than 400 trains a day in each direction.

It may be asked if such a development would be of a nature to bring an important increase of traffic. The reply is self evident when it is remembered that the electrified line from the Invalides to Versailles has shown traffic increases of from 12 to 13 per cent. per year, while the other steam lines showed increases of barely 2 or 3 per cent. Another electrified line in Paris, with similar conditions and results, could be cited. Many other examples, especially in England, could be quoted, so that the result of electrification is not in question.

Organisation of Traffic with Electric Traction.—A very complete examination of the variation of the traffic with regard to the time of day, the season of the year, and the sections of the line, has led to the employment of a single type of electric carriage, built to contain all the elements required for suburban service, namely, guard's van and first and second class compartments. This coach can carry 100, including strap hangers. It is to be remembered that third class has long since been done away with on the suburban lines, except on the Argenteuil section, where it will shortly cease to exist. During much of the time the service will be carried on by single coach trains, the number of seats being amply sufficient at such hours. During the time of heavier traffic and on the more busy sections the trains will be composed of several similar coaches. It is intended to run special electric trains for parcels service, which in the suburbs is developing more and more. To find out how many coaches to allow on each section of the line, statistics of the hourly traffic at each suburban station have been compiled over a long period of time, and it is possible with the help of these statistics to find out for each line and within each zone the number of seats required hour by hour.

The Choice of the Electric Traction System.—The various systems of electric traction in current use may now be briefly dealt with in order to justify the choice made by the State railways. Amongst these systems 3-wire, continuous-current, and 3-phase traction call for three conductors, which reduce to two if the return is by the track rails. They have been applied with great success in certain cases, for example, the Nord-Sud has successfully employed continuous current on the 3-wire system, using as conductors an overhead wire and a third rail, each at 600 volts, the track rails serving as the neutral wire. A system has thus been evolved which by suppressing the return current and its drop in pressure is completely innocuous, so far as electrolysis is concerned. A number of examples can also be given of the application of the 3-phase system, among the more recent those of the Simplon and the Mont Cenis installations (two overhead conductors with the track as the third phase). But these two systems, as can be understood, are exceedingly complicated at station crossovers and at important junctions. The 3-phase system, moreover, hardly lends itself to rapid acceleration, and is useless for multiple-unit working.

The other systems only employ two conductors, one of which is, in almost every case, the track rail. These systems are the single-phase system and the continuous-current system. The single-phase system permits the use of high voltages on the working conductor; it is therefore possible to use a light overhead wire. The continuous-current system, if normal pressures of 500 to 700 volts are used, is, on the contrary, only available with a heavy steel conductor about ground level. If use is made of higher pressures, such as 1,200, 1,500, and even 2,000 volts, which the construction of modern motors allows, either an overhead line may be used, which has to be very heavy in the case of dense traffic, and is consequently expensive and ugly, or else the conductor must be installed near the ground.

The author ventures to think that the day is at hand when a satisfactory solution of these difficulties will be found, although the solution may not be a simple one. As yet there is no installation of this nature, and a choice must be made between the single-phase systems and the continuous-current system at a normal pressure of 600 to 700 volts.

With the single-phase system there is a considerable simplification in distribution from the use of static transformers in place of sub-stations with rotary converters; there is also a saving in the number of attendants, better efficiency, and freedom from electrolysis troubles.

With the continuous-current system, the equipment of the coaches is much lighter and less cumbersome, the acceleration more rapid, with a better efficiency of the motors, and lastly, less waste of energy per useful ton carried. From the point of view of safety, the continuous-current system does not require the current to be taken above the floor of the coaches. It does away with all the trouble (in particular at crossovers and for branch lines at large stations) of the overhead wire (in the case of a derailment, the upsetting of poles, or the fall of several parallel wires, &c.).

Protection against lightning is more easily made than with an overhead single-phase wire. In numerous recent railway investigations for particularly heavy traffic, the continuous-current system has shown a real superiority to the single phase on the economic side. Without attempting to go too deeply into the matter the author would draw attention to the following chief points: The stationary installations are cheaper for single phase than for continuous current (sub-stations and tracks). On the other hand, the equipment of the rolling stock is both heavier and more costly. It is quite understandable, therefore, that the heavier the traffic the greater the advantage of the continuous-current system. It is the same with the working expenses, the more the installation is fully utilised, the lower is the expense per ton carried by the continuous-current system as compared with the single-phase system, chiefly owing to the weight of the equipments.

The author will not go so far as to repeat what was said at the last Railway Congress at Berne in 1910, namely, that the single-phase system is the one which ought to be employed when all hope of increasing the traffic has been lost. He has, in fact, made use of it himself in certain cases, and it cannot be doubted that it has its own special field. But it cannot be repeated too often that it is not applicable in every case, and the one under discussion appears to be an instance where it is not at all suitable.

A word on the subject of electrolysis. The care taken in the upkeep of the permanent way and conductors from the Invalides to Versailles left bank (rail of 46 kg. per metre mounted on insulators, good condition of the ballast, the level of which is always kept below the rails) has prevented any trouble during the whole 10 years the line has been at work. For lines where the traffic is heavier, the effects of electrolysis may be expected to be greater and to show themselves sooner. There is reason, however, to think that where the construction is good and the upkeep of the track satisfactory there will be little trouble. On the other hand, as regards the single-phase system, it is necessary to include the difficulties caused to telegraph and telephone transmission, which are not yet overcome. For all these reasons, and particularly since on most of the sections the density of the traffic is already very high and is bound to increase, the State railways, being anxious to make no mistake, have adopted the continuous-current system at 650 volts. This system is sanctioned by long usage, it is thoroughly reliable, and in the present instance it is certainly the cheapest.

Our neighbours, the English, a practical people, after the very interesting application of the single-phase system on the part of the London, Brighton, and South Coast Railway on several lines in the south of London, have just recently, like the State railways, adopted the continuous-current system at 650 volts for the majority of the lines in the suburbs of London. It must be added that everything that exists in Paris in the way of heavy electric traction: Métropolitain, Nord-Sud, Orleans (Orsay Juvisy), État (Invalides-Versailles, left bank), is worked with continuous current at 650 volts.

The Electric Power Station.—For the electrification under consideration the electric supply must be able to furnish 400 to 500 motor-coaches with continuous current at 650 volts, through a third rail parallel to the track, the running rails serving as return conductor. The current is furnished by sub-stations receiving energy in the form of alternating 3-phase current at 25 cycles, 15,000 volts, from the generating stations. To avoid trouble from frost after a thaw, a conductor rail with under collection was proposed. This rail weighs 76 kg. per metre. It is carried by supports of impregnated wood of a type similar to that used on the Invalides-Versailles line. The motor-coaches collect the current by a special shoe, called "universal," arranged so as to collect either from the upper or under surface of the rail.

The sub-stations, placed wherever possible at junctions, contain rotary converters of 1,500 kw., 1,000 kw., and 750 kw. output, according to their importance. Their distance apart varies from 3 km. to 8 km., according to the density of the traffic. Almost in every case they serve also to supply energy to the railway stations or to the station approaches. A very interesting control system allows a certain variation in the voltage of the continuous-current supply, and of several sub-stations being put out of action during slack hours. The starting of the rotary converters is effected from the alternating side throughout. The sub-stations are supplied by 3-phase underground feeder cables at 15,000 volts, 25 cycles. The pressure of 15,000 volts was chosen, first, because underground cables were used; second, on account of the distance to be fed, so as to step down at sub-stations without very elaborate apparatus, the network being very complicated. The feeders, it should be noted, are in duplicate, to ensure complete security. Electric energy will be furnished by two power stations, the construction and working of which has just been entrusted, after public tender, to an industrial syndicate. There is a sliding scale of charges under which, when the stations are finished, electric energy will be sold to the State at an inclusive charge of about 5 centimes per kilowatt-hour.

The two power stations, comprising steam turbine units of 5,000 kw., will be placed at Moulineux and at Bezons on the banks of the Seine. When the installations are complete, they will have a capacity of about 60,000 kw., and will furnish the State with about a hundred million kilowatt-hours per annum. The sliding scale for supplying this current contemplates the ultimate utilisation by the State of the energy coming either from the Rhône or from the coal mines in the north. It must not be forgotten that Bezons is only 170 km. from Lens. There is, therefore, good reason for believing that before long the coal mines at Pas-de-Calais will join with the falls of the Rhône in supplying Paris with electricity through a network of feeders, combined in a system such that the seasonal, daily, and hourly variations in the demand for energy at the points of consumption, are met by corresponding variations at the various points of supply, arranged so as to secure the maximum economy.

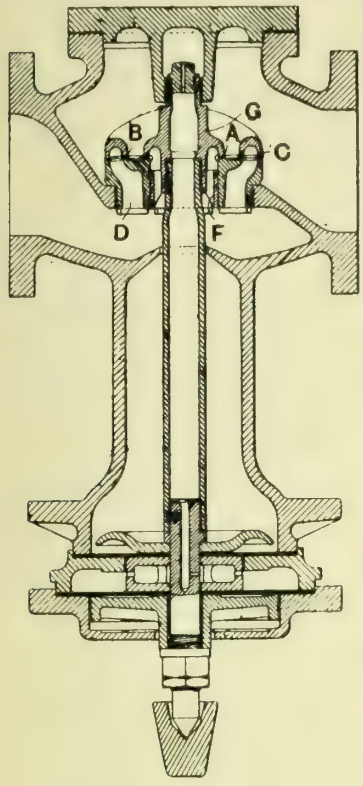
As regards subsidiary works, it may be mentioned that several engine-sheds and a large repair shed at Garelle-Bezons are to be provided for maintaining the electrical rolling stock. This shed, now in course of construction, will be able to take at one time 40 to 50 coaches, and will be equipped with modern cranes and up-to-date tools. One result, and not the least important result of the electrification will be the distribution of electric energy under the most economical conditions to all suburban stations.

British Acetylene and Welding Association.—At the annual general meeting of this association, recently held in London, the retiring president, Mr. K. S. Murray, read a report of the work of the association during the past year. In this he stated that the association stood in a stronger position to-day than it had ever previously occupied, and was now better able to render assistance directly and indirectly to the acetylene industry. The total membership had more than doubled during the year, and it was not unreasonable to anticipate that before long the association would carve its way into a position of importance as an independent and representative organisation, valuable not only to the acetylene trade itself, but to those trades in which to-day acetylene played such a useful part. The by-laws had been modified so as to enlarge the scope of the association, and to cover the welding and metal-cutting processes which had in recent years become so helpful to the acetylene industry. Mr. Ernest W. Sprott was elected president for the present year; Mr. T. G. Allen, vice-president; and Mr. H. E. Baker, treasurer.

Incorporated Municipal Electrical Association.—The eighteenth annual convention of this association is to be held in London from Tuesday, June 17th, to Saturday, June 21st. The meetings will be held at the Institution of Electrical Engineers, Victoria Embankment, where on June 17th the Convention will be opened at 10 a.m. by Mr. W. Duddell, F.R.S., president of the Institution of Electrical Engineers. An address will then be delivered by Mr. C. E. C. Shawfield, and a paper will be read by Dr. S. Z. de Ferranti on "Prime Movers for Electric Power." On Thursday, June 19th, the meeting will be held at the Empire Theatre, Kingston-on-Thames, when a paper on "Air Filtration" will be read by Mr. J. Christie, chief electrical engineer, Brighton, and on "Electrical Vehicles" by Messrs. W. H. L. Watson and R. J. Mitchell. A council meeting and the annual general meeting will be held on Friday, June 20th, at the Institution of Electrical Engineers. A number of interesting visits and excursions in London and the environs have been arranged for. Application should be addressed to the secretary of the association, Mr. C. McArthur Butler, F.C.I.S., 28, Bedford Square, W.C.

DEWRANCE'S REDUCING VALVE.

The accompanying sectional view shows a design of reducing valve, the invention of Mr. John Dewrance, 165, Great Dover Street, Southwark, London. In valves of the kind under consideration, the initial pressure acting on the under side of the discharge valve, which controls the discharge orifice, is balanced by a diaphragm-mounted piston. In the design illustrated a special construction of discharge valve is employed which enables the diameter, as also that of the diaphragm, to be reduced; thus materially reducing the size and cost of the entire apparatus. When a single-seated valve of the ordinary character is employed, a single annular passage is formed about the outer edge of the valve for the escape of the steam. Under such circumstances, owing to the limited range of movement of the diaphragm, the lift of the valve is so restricted as to afford insufficient area for the passage of the steam to be controlled; but in a reducing valve provided with the special construction of discharge valve, the diameter thereof, as also the lift of the valve, is reduced, whilst the discharge area of the latter is increased.



DEWRANCE'S REDUCING VALVE.

The discharge valve is guided centrally and is formed with three concentric seatings A, B, C, which control two concentric passages D, F; there being moreover between the inner seating A and the intermediate seating B an annular passage through the valve G. When the valve is lifted off its seat, the steam passes outwardly past the inner seating A, inwardly past the intermediate seating B and outwardly past the outer seating C; thus providing three annular discharge passages, instead of one, as in the case of the ordinary or single-seated valve.

THE USE OF THE ELECTROSTATIC SYSTEM FOR THE MEASUREMENT OF POWER.

At a recent meeting of the Institution of Electrical Engineers a paper by Mr. C. C. Paterson, Mr. E. H. Rayner, and Mr. A. Kinnes, on the above subject, was read. The authors mentioned they had used the electrostatic system for all their alternating current measurements at the National Physical Laboratory for upwards of six years. The instruments consisted of electrostatic voltmeters and an electrostatic wattmeter, together with the supplementary apparatus which enabled commercial alternating-current instruments of any range and of the highest precision to be calibrated with ease and certainty. The accuracy attained was considerably better than five parts in 10,000; and the long experience gained in the every-day use of the instruments had convinced the authors of the great value and convenience of the system in the work of a central testing laboratory. There was no suggestion that the electrostatic wattmeter should take the place of any of the existing precision instruments used in station work—for this purpose it would prove troublesome—but where a system was required of the very highest accuracy, combined with a wide range of application and convenience in use, the authors were of opinion that at present there was none to be compared with the electrostatic system.

The apparatus which they had developed had been evolved to meet the special requirements of the electrotechnical instrument-testing section at the laboratory. Two of the principal requirements of the work were: (1) A high degree of accuracy, and (2) adaptability over a wide range for measuring all kinds of loads met with in the testing laboratory. The outstanding advantages of the electrostatic system for the measurement of electrical quantities, as distinct from the system of using instruments of the dynamometer type, were (1) The wide ranges of current and voltage over which a single standard instrument could be used. The voltage range of dynamometer wattmeters could be multiplied indefinitely; but errors were introduced when the current to be measured exceeded one or two hundred amperes. One of the chief troubles was due to the heavy metallic windings of the series coils, and the disturbance of their fields in consequence of eddy currents. The electrostatic wattmeter, on the other hand, could be used to measure practically any current. The authors at present went up to 3,000 amperes in alternating-current power measurements; but if there were a demand for tests involving larger currents, it could be met readily. (2) The fact that the voltmeter and the wattmeter required but a minute capacity current enabled them to be changed over from one circuit to another without causing any disturbance as, for instance, when measuring 3-phase systems by the 2-wattmeter method, or when measuring the ratios of potential transformers. (3) Eddy currents did not arise in the apparatus to affect its accuracy in any circumstances met with in practice. (4) The instruments themselves were independent of changes in frequency or in wave-form. The shunts which were used with the wattmeter for currents of 1,000 amperes and over had, however, a very small effective inductance, which should be allowed for when high accuracy at very low power factors was required. For instance, the 3,000-ampere shunt introduced an error of 0·8 per cent. in wattmeter readings at 0·1 power-factor and 50 cycles per second. The form of the shunt enabled the inductance to be readily calculated, and a correction for the only factor affecting the accuracy could thus be applied. As, however, the accuracy was affected only when the largest currents and lowest power factors were in question, it was seldom necessary to take this error into account. (5) The instruments were all of the direct deflection type, and their scales could be read easily and accurately with the naked eye.

The chief disadvantages of the system were: (1) The relatively small controlling forces in the electrometers causing the slow movement which was common to most electrostatic instruments. (2) In order to keep down the time of swing of the wattmeter moving system (undamped) to about 8 secs. and yet leave the instrument robust enough to withstand ordinary every-day use, it was desirable to work with a pressure of about 2 volts on the quadrants for full deflection over the scale. This meant that a pressure drop of one or two volts was wanted, whatever the current through the series resistance. Two volts with 2,000 amperes meant a dissipation of 4 kw. in the resistance; this was readily managed with water cooling, but the introduction of the water system must be regarded as a disadvantage. Considerable benefit, however, accrued from the use of these resistances, as they formed a good non-inductive load for the transformer and generator supplying the current and thus helped to prevent wave distortion of the generator and to keep 3-phase circuits balanced. Their relatively high resistance also helped to produce a low time-constant. (3) The instruments were not portable. When once set up and adjusted they were best left alone. (4) Most of the apparatus must be regarded as "special," since there was never likely to be a sufficient demand for equipment of this nature to cause it to be manufactured in commercial quantities.

Metal Cutting under Water.—Oxyhydrogen-flame working under water is said to be accomplished successfully by means of a special form of burner recently invented. This burner consists of an ordinary oxyhydrogen burner with the addition of a bell or hood shielding the gas orifice from the water, and a compressed-air supply. A. Heckt, of Kiel, Germany, (12, Lübecker Chaussee), is marketing the apparatus. Successful demonstrations have been made with the apparatus, during which a bar of iron $2\frac{1}{4}$in. square was cut through in 30 seconds at a depth of 16ft. under water, and a 12in. slot was cut in $\frac{13}{16}$in. plate in $1\frac{1}{2}$ minutes.

APPLICATION AND PRODUCTION OF DIE CASTINGS FOR AUTOMOBILES.*

BY WALTER BETTERTON.

(*Concluded from page 592.*)

WE now come to the construction of the dies themselves. As a rule, they are made of mild steel, the exceptions being heavy bases and frames which are made of cast iron, dowel pins and small cores which should be made of tool steel. Except in rare instances, the die should have no hardened parts, because the melting points of some of the alloys will be high enough to soften such surfaces. The following are a few of the essential

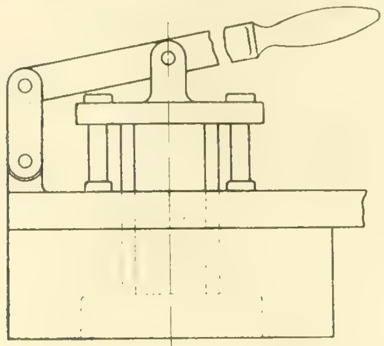


FIG. 3.

considerations in making dies. Means must be provided for facility in ejecting the castings upon completion. This is usually done by ejector pins, as shown in Figs. 3 and 4, although frequently it would be better to have the bottom of the die or some other section movable and perform the ejection on the same principle that is used in drawing dies of the combination type. The next question is that of air vents. In the case of a die in which air is exhausted by the incoming molten metal, air vents are necessary at frequent intervals around the die cavity in order to prevent the air from pocketing. These vents are made by milling a shallow slot in the joint face of the die, the general practice being $\frac{1}{4}$in. to $\frac{1}{3}$in. wide, and from ·003in. to ·005in. deep, varying with the size and shape of the die. Air vents for a die in which a vacuum is obtained will be shown in the diagram illustrating a machine operated on this principle. For making die-castings that are to have pieces of other metal inserted, it is necessary to use a die with provision for receiving the metal-blank, and holding it only while the metal is cast round it. Of course, the piece must be held in such a way that it can be easily ejected from the die with the finished casting.

In order to maintain the die at a constant temperature, the usual practice now is to water-jacket them. A difficulty is sometimes encountered due to shrinkage, in which case a

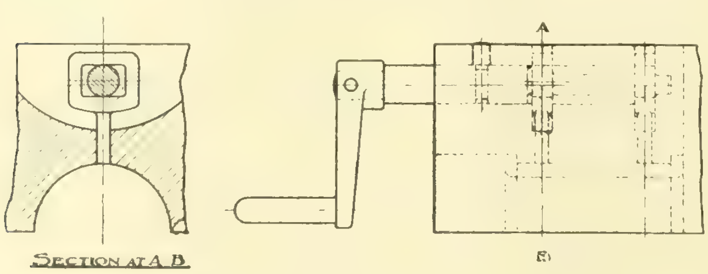


FIG. 1.

sample casting should be made, and if it is found to be incorrect, the dies must be altered. When doing this sufficient material must be allowed for grinding away, the casting in the first place being made somewhat too small in order to admit of this.

A most necessary feature in all dies is the sprue, or gate cutter. The object of this is to enable the hole, through which the molten metal is forced, to be as large as possible and at the same time to have a large volume of metal at the opening. This also helps to maintain the temperature of the metal while it is being forced into the die, and further, this, to a very large extent, also ensures all the crevices of the die being filled before the metal commences to set. Therefore, the greater the opening through which the metal is forced, as also its volume, the fewer will be the blow-holes. Immediately the die is filled, the large volume of metal is cut off by the operation of the sprue cutter.

If the piece to be die-cast has a centre hole, the sprue cutter is very easy to construct, as shown by Fig. 5. If the hole is straight, it is immaterial whether it is round, square, or any other shape. When castings have no centre hole, the sprue cutter can be placed at the end of the casting, as shown by Fig. 6. The joints in the die should, wherever possible, be made on the edge of the piece, in which case, after the casting has been trimmed, the joint will be practically invisible.

I have mentioned the chief points to be considered in the construction and design of dies, and I have also described the various parts common to all dies. Apart from this, the design of a die for any particular piece must be considered on its merits. Time will not permit of my giving a detailed description of the method of constructing dies for various kinds of parts. I propose therefore to describe one for the most common die-cast part, viz., a half-round bearing. A die suitable for this is shown in Fig. 7. It consists of upper and lower parts (A and B) which are held rigidly together by the dowels C. On the lower half is located the main core D, and in this are the cores E for the oil grooves. It also contains a set of ejector pins F operated by levers G. The upper half is simpler. The depression conforms to the outside of the bearing and contains the ejector H which, when drawn back, forms the dowel or bearing-keep. This is operated by levers I for ejecting the casting should it stick to the top half of the die. Both halves

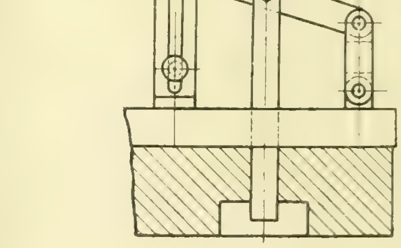


FIG. 5.

contain corresponding gate holes J, in which the gate or sprue cutter operates. When in use the die is fastened between the upper and lower halves of the die vice, which is placed directly over the casting machine, the ejector pins are drawn back, after which the gate is turned back to allow the metal to enter. Pressure is then applied to the metal, and when the die is full the gate is sheared off while the metal is still more or less molten. The result of this method is that the place where the sprue has been cut off from the body of the casting is almost imperceptible, a great advantage in this respect over the ordinary method of sand casting, where large sprues have to be cut off cold. The dies remain closed only long enough to allow the casting to set. When it is opened and the ejector pins are thrust forward by means of the levers G and I the casting is loosened from the main cover, where it usually sticks a little. It is essential that ejector pins and sprue cutters should be a good fit, so as to prevent the metal from getting between the working surface, thus causing it to "freeze" and lock the pieces, which would make it impossible to operate them.

Some means must be provided whereby the density of castings can be ascertained without spoiling them or resorting to the common practice of fracturing—a test which naturally can only be applied to one here and there. Further, it is desirable to ascertain their density as compared with that of the ingots. As the latter are cast in open moulds, and are therefore free from blow-holes, and porosity, the user of die-castings could hardly demand that they should be of greater specific gravity than the alloy ingot itself, although, as a matter of fact, castings produced by the double-vacuum process are claimed to be slightly denser than the ingot, owing to the method of com-

* Paper read before the Graduates' section of the Birmingham Branch of the Institution of Automobile Engineers, April 8th, 1913.

pressing the metal in the die. An apparatus whereby the volume of a casting can easily be obtained by the displacement of water should be designed. When making the test it is only necessary to ascertain the volume of one of each design, after which each casting should be weighed, rejecting any which do not come within specified limits. These limits would be previously determined in view of the duty and conditions which the finished casting had to fulfil. It will thus be seen that if the specific gravity of the ingot is determined previous to the die casting, and the specific gravity of the casting determined afterwards, a definite basis of comparison is obtained.

It would be desirable for any who buy their die-castings to test the density of all deliveries. In this case, the density of

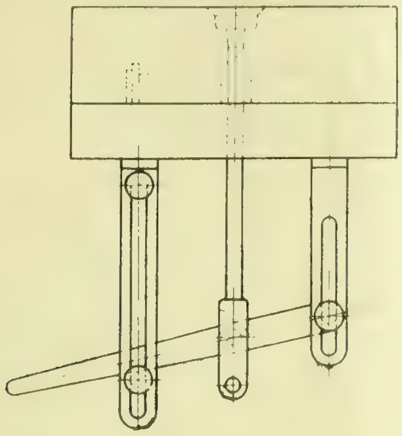


FIG. 6.

the ingot would not of course be known, so that the only way of testing would be to weigh each one on finely-adjusted scales. Seeing that, as I have already shown, the castings would all be within, say, one thousandth of an inch in size, they should all be practically the same weight. If the weight of any of them fell short to any serious extent, it would be obvious that they contained blow-holes.

In the design of die-casting machines, it is essential that the metal should be handled as little as possible, so as to prevent oxidation. The molten metal should be covered in so that the air may not strike it more than necessary.

The principle of using air to operate different parts of the machines, such as pressure levers, sprue cutters, casting ejectors, &c., is very good, but considerable care must be

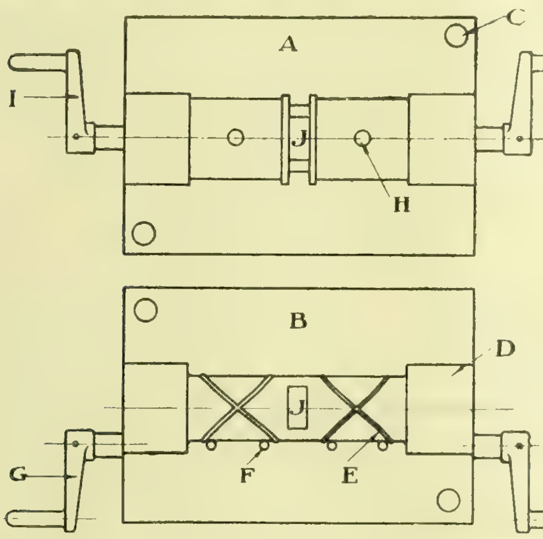


FIG. 7.

exercised to ensure that no metal may be trapped in any part of the machine and become solid. When this occurs, it is necessary for the machine to be taken apart and cleaned before it can be operated again.

The following are a few hints which, if observed, will make all the difference between good and bad castings. Before commencing the casting operation the dies should be heated slightly. After each casting operation the dies should be cleaned by air blast.

The metal should be kept just above the melting point and at a uniform temperature. If the metal is worked too cold, the result will show itself in castings that are full of seams and creases, and it will be difficult to fill the thin parts of the die. If, on the other hand, the metal is too hot, the die will throw excessively long fins at the joints, &c., the casting will not cool as quickly in the die, and this will consequently reduce the output.

When fresh metal is put into the tank, it should be heated previously in a separate furnace, so that the new supply will not reduce the temperature of the metal being worked.

Casting-dies require lubricating frequently, beeswax being most commonly used. The lubrication consists merely in rubbing the cake over the surfaces of the die cavity.

I propose now to deal with the design and method of operation of three types of die-casting machines: (1) The Soss machine, plunger type, Fig. 8. (2) The Grey machine, compressed air double vacuum type, Fig. 9. (3) The Von Wagner machine, compressed air goose-necked type, Fig. 10.

The Soss die-casting machine, which is one of the hand type, is of comparatively recent origin, and it is also claimed to be the first die-casting machine to be placed on the open market. Fig. 8 shows the principle of this machine. A is the base and frame of the machine. B is the heating chamber, and within this is the tank C. This contains the metal from which the die-castings are made, and is heated by burners D which are fed with gas and air. Through the bottom of the tank, well to the inner side of the furnace, runs the cylinder E, the orifice of which is controlled by the gate F. In the same cylinder at the bottom of the pot itself is an opening G that allows the metal in the pot to run into the cylinder from the tank. H is the plunger used for forcing the metal into the

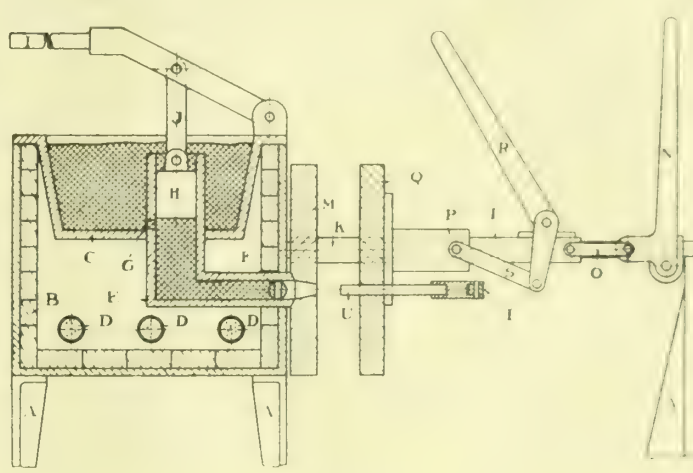


FIG. 8.

die. I is the compression lever which is connected by J to the plunger. At the opposite end of the furnace is the mechanism for operating the dies. This consists of a pair of square rods K upon which are mounted the sleeves L which are attached to the die-plate M. Lever N, at the end of the operating mechanism, controls the movement of the sleeves by means of links O. Upon these sleeves is mounted a secondary set of sleeves P attached to the other die-plate Q, and whose movement is controlled by lever R through links S. This second set of sleeves is free to travel with the first, and in addition has an independent movement of its own on the primary sleeves. It is the function of the lever R to bring the die-plate Q up to the die-plate M by means of the links S and sleeves P, and it is the function of the lever N to bring both die-plates up to the outlet of the cylinder. This system of sleeve mounting is one of the distinctive patented features of this machine. The orifice of the cylinder E is conical in shape, and fits the cup-shaped opening in the plate M, so that when the two are brought together the joint is metal tight. At the centre of the opening and extending through the die-plate M is another opening that leads to the dies mounted on the inner faces of the two die-plates, and a continuation of this opening extends through die-plate Q in which the sprue cutter U works.

An important feature in this machine is that the metal for the casting is taken from the bottom of the melting pot, where the metal is always best. Another feature is the construction of the plunger. In the early plunger-types of machines much trouble was encountered due to the top end of the plunger

protruding out of the metal, the result being that the plunger was more or less cold at the top and the metal used to get between the working surfaces of the plunger and cylinder and then freeze, so locking the plunger. Until the machine had been taken apart and cleaned, it was impossible to operate it.

Fig. 9 shows the method employed by Mr. C. M. Grey to obtain a vacuum at the back of the metal to be cast. At the same time a vacuum is obtained in the die. This illustration is taken from the patent specification and serves only to show the principle of the apparatus. In this A and B represent the two parts of the die-body, and C the die-cavity, shaped to the

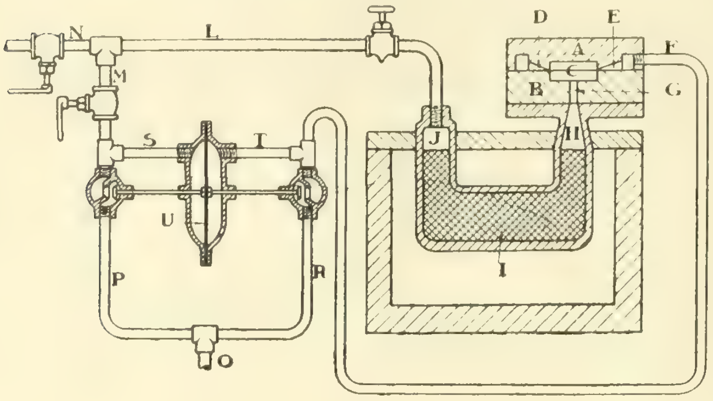


FIG. 9.

form of the casting desired. D and E are the air vents through which the air is exhausted from the die by means of the pipe F. G is the gate of the die, which latter rests directly over the spout H of the metal pot I. In actual practice there is a valve, or plunger, for the purpose of closing the gate and shutting off the metal when the die is full. At the end of the metal pot opposite the spout is the vacuum chamber J to which the pipe L is connected. This pipe not only connects with the vacuum pump M, but also to the compressed air pipe at N. The exhaust pipe O has two branches P and R which lead to the vacuum chamber of the pot, and to the die through the valves shown in each branch. The pipes S and T lead from the two exhaust pipes above the valves to the chambers on opposite sides of the diaphragm U, so that excess of vacuum in either the metal pot or the die will cause the diaphragm to move towards the side on which the vacuum is the greatest, partly closing the valve on one side and correspondingly opening the valve on the opposite side. In this way an equal vacuum is obtained on both sides of the melted

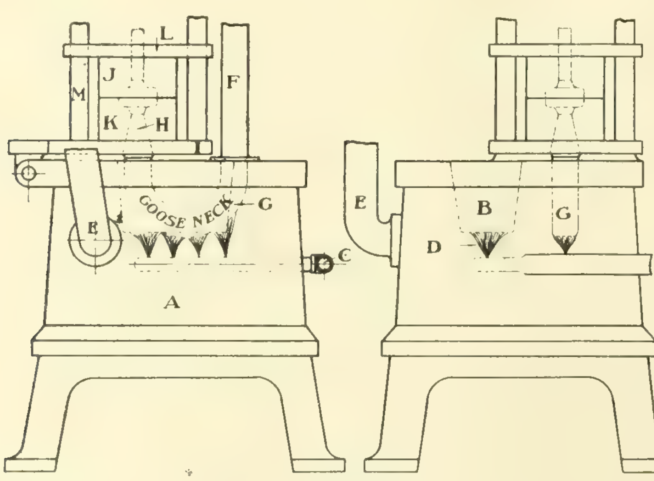


FIG. 10.

metal, and prevents the entry of air, gas, or molten metal into the die. When the balance vacuum has reached the desired amount, as indicated by the gauge, the suction is shut off at M and compressed air is instantly let in at N and this passes through the pipe L, forcing the melted metal up into the die. It is claimed that this method effectually prevents porosity or blow-holes in the finished casting.

Fig. 10 illustrates the principle of the die-casting machine used by the van Wagner Company, of America. A is the base of the machine in which is located the melting pot B. This melting pot is heated by fuel oil passing through the supply pipe C to the burners D. E is a vent pipe provided to take away the gases incident to combustion. F is the compressed air pipe for conveying the metal into the die cavity. The pressure is regulated to suit the particular casting or die, the correct amount being determined by experiment. Similarly, there is an air exhaust pipe which may be directed above the supply pipe, and which is sub-divided into two tubes extending to the die-cavity, for the purpose of exhausting the air before

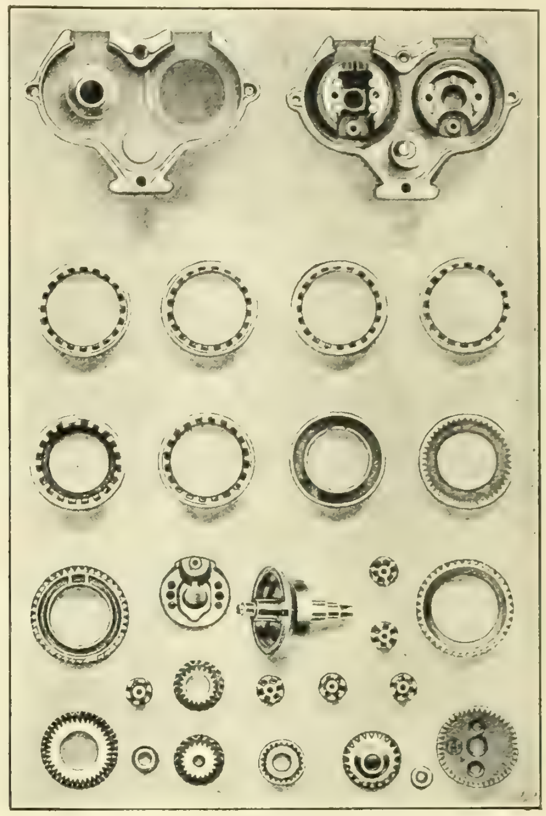


FIG. 11.

the metal is admitted. There are two methods of overcoming the difficulty of air being in the die, namely, the exhaust and the venting method, and it is the former that is used on this machine. Goose-neck G serves to contain the metal for immediate use, which is forced into the mould. An amount of metal slightly in excess of that required for each casting is put into the goose neck with a hand ladle previous to each operation of the machine. One end of the goose neck is connected with the compressed air pipe F, while the other end

FIG. 12.

FIG. 13

FIG. 14

terminates in a nozzle H. One of the advantages in using the goose neck is that the entire air pressure is expended upon the metal in the goose neck, and, by reason of its isolated position, the goose neck and its contents are kept slightly hotter than the contents of the melting pot. The die-holding mechanism is supported by the lower die-holding plate I, which is hinged to the edge of the base of the machine. The lower half of the die K is mounted on the die-holding plate I, and the upper half J is mounted on the die-holding plate L.

For the benefit of those who are not familiar with the possibilities of die-casting a few fine examples are reproduced in Figs. 11-16. The author wishes to thank all those who were kind enough to supply him with sample die-castings for use at the reading of this paper; also the Industrial Press, New

York, for their kind permission to reproduce Figs. 8 and 10, and Messrs. C. M. Grey Company, of New Jersey, for their kind permission to reproduce Fig. 9 from the "American Machinist." In addition, the author wishes to express his indebtedness to "Machinery," for enabling him to keep track of the developments on the other side of the water.

THE ECONOMY OF DRY BLAST.*

BY PROF. JOSEF VON EHRENWERTH, DR.ING.

IN previous discussions upon the influence of the moisture in the blast upon the fuel consumption in blastfurnaces, the calculations which have been made, taking into account the summer and winter extremes of atmospheric conditions, show that the theoretical consumption of fuel should be about

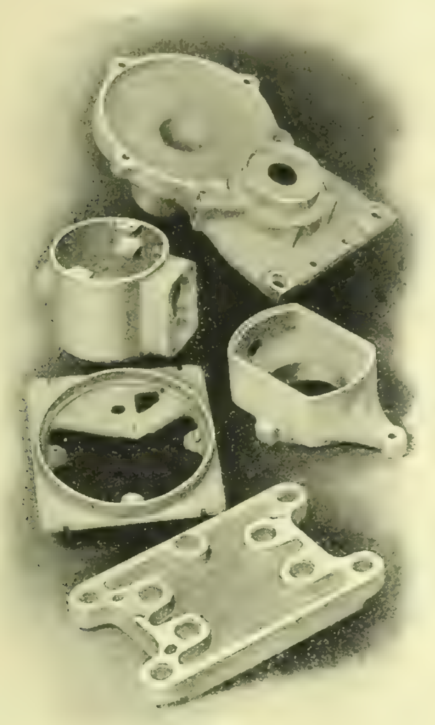


FIG. 15. DIE CASTINGS.

1 cwt. less in winter than in summer for every 25 cwts. of pig iron smelted, these figures being based upon local (Styrian) practice with well-sheltered charcoal blastfurnaces running on white iron. Actual practice shows that the difference in fuel consumption in the extreme summer and winter amounts to about three-quarters of a hundred-weight per 25 cwts. In the theoretical calculations it was assumed that all other conditions except the degree of moisture in the atmosphere remained the same.

Gayley's system, as practised at the Etna blastfurnaces, consisted in freezing the moisture out of the blast, and he stated that by reducing the moisture from 13 grammes to 4 grammes per cubic metre he had realised a saving of 20 per cent. in fuel, an increase of 24 per cent. in the production, the lowering of the temperature of the waste gases from 280° C. to 190° C., and the raising of the temperature of the blast from 390° C.—400° C. to 466° C., without interfering with the regular working of the furnace. The coke used contained 10·5 to 12·5 per cent. of ash.

This astonishing announcement and other later reports† induced the author to make a closer investigation of the matter, his first endeavour being to solve the following question: What is the amount of fuel required to supply to the furnace a constant quantity of effective free heat (1,000 calories) under varying conditions of atmospheric moisture, and under different blast temperatures and temperatures of waste gases, and with varying heat losses due to conduction and radiation?

Calculations were made with charcoal assumed to contain 2 per cent. of ash and 7 per cent. of water, and with coke containing 8·5, 12·2, and 15·6 per cent. of ash, with 3 per cent. of volatile matter and 5 per cent. of water (calculated on the carbon content). Various degrees of blast temperature and waste gas temperature were assumed, as well as various percentages of loss by radiation.

The author proposes to pass in review the principal results obtained assuming the use of the first two kinds of coke referred to, with blast differing by temperature intervals of 400°, and with waste gases differing by temperature intervals of 50° and 100°, and assuming the heat losses by radiation to be 10 per cent. in some cases, and in others to vary with the increasing temperature of the waste gases. These results are represented graphically in the accompanying diagram.

Diagrams 1 and 2 relate to coke containing 8·5 per cent. of ash, and diagrams 3, 4, and 5 to coke with 12·2 per cent. of ash. The ordinates of the curves for the waste gas temperatures, within the three spaces indicating the range of the blast temperature, represent the amount of fuel required to produce 1,000 calories of free heat with varying amounts of moisture in the blast, the proportion of moisture being represented by the abscissæ. Diagrams 1 and 3 are plotted on the assumption that the heat losses = 0; in diagrams 2 and 4 it is assumed that the heat losses amount to 10 per cent., and in diagram 5 that the heat losses increase from 9 to 18 per cent. with the increased temperature of the waste gases.

From the results obtained, the following conclusions may be drawn:

(1) That the economic advantage of drying the blast is greater the lower the temperature of the blast and the higher the temperature of the waste gases at which the furnace previously worked. This results naturally from the saving in fuel, from the smaller expenditure of heat in decomposing the small amount of moisture left in the blast, and from the formation of a smaller quantity of gases, which give up their heat more quickly and completely as they rise through the furnace more slowly and escape at a lower temperature. The

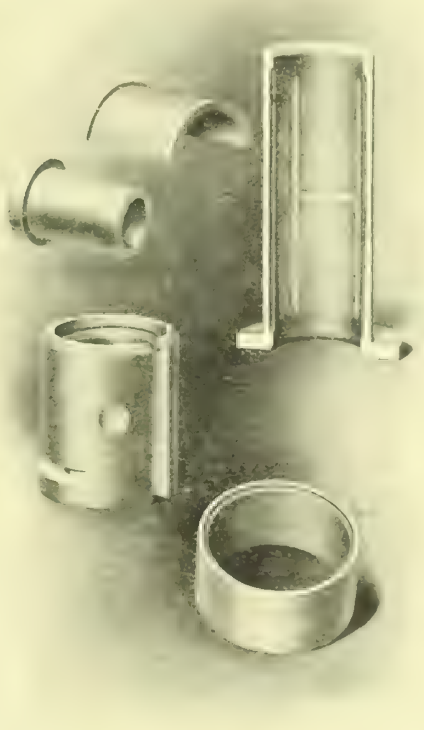


FIG. 16. DIE CASTINGS.

* Abstract of paper read at the annual meeting of the Iron and Steel Institute, May, 1913.

† Gayley reports concerning a blastfurnace in the West that the average result of six years' working with dry blast showed a 10 per cent. saving of fuel and 12 per cent. increase of output. Of another blastfurnace it is reported that the saving in fuel amounted to 7·5 per cent., and the output was increased by 23 per cent. In each case a more regular working of the furnace had been observed ("Stahl und Eisen" 1911, p. 583). In the case of the Warwick blastfurnace at Pottstown, Pennsylvania, it was calculated that by the reduction of the moisture in the air from 9 to 3·5 grammes per cubic metre a saving of 21 per cent. in fuel and an increase of 23 per cent. in production had been obtained on a production of 750 tons daily. The temperatures of the blast and waste gases when working on foundry pig were 540° and 260° C., and when working on basic pig iron 480° and 150° C. respectively. At the works of Guest, Keen, & Nettlefolds at Cardiff the result of dry blast working showed a saving in fuel of 13·4 to 18·1 per cent., and an increase in output of 14·1 to 26·4 per cent.

heat losses due to conduction and radiation are therefore also reduced in proportion as the waste gas temperature is lowered.

(2) In consequence of the economy in fuel the total quantity of material charged, and therefore also its volume, is less and the volume of blast required is smaller per unit of production. If the periods between tapping remain the same, the blowing engine and stoves, without increasing their duty, can cope with a larger production, and the furnace yield is therefore increased, as is in general proved to be the case in practice.

(3) The quantity of gas formed within the furnace being less owing to the drier condition of the blast the temperature in the melting zone must be higher. The melting process is therefore not only accelerated but the silicon percentage is increased, and the quality of the pig iron as regards sulphur is improved. This too has been found in practice to be the case.

The removal of 5 grammes of moisture per kilogramme of air is accompanied by a rise in temperature of about 32° to 35°, which corresponds to an increase in the temperature of the blast of about 40° to 45°. In this respect the drying of the blast is similar in effect to the heating of the blast, though with the important difference that, by drying, the quantity of the waste gases diminish, whereas by heating only, it remains the same.

(4) Another natural consequence of using blast with a uniform quantity of moisture, such as can be effected by drying, a more regular working of the furnace is assured, an advantage which Gayley regards as superior to that of economising the fuel. As is well known the fuel charged into the blastfurnace adjusts itself to the performance of three functions during the course of the whole process, namely, one portion (F_r) effects reduction, another (F_c) the carburisation of the iron, a third (F_h) is utilised for heating, while a portion (F_w) is wasted through being carried off in the form of dust in the gas.

If the percentage economy of fuel per unit of pig iron be denoted by E_f and the percentage saving of the heating fuel (F_h) denoted by E_h, then:—

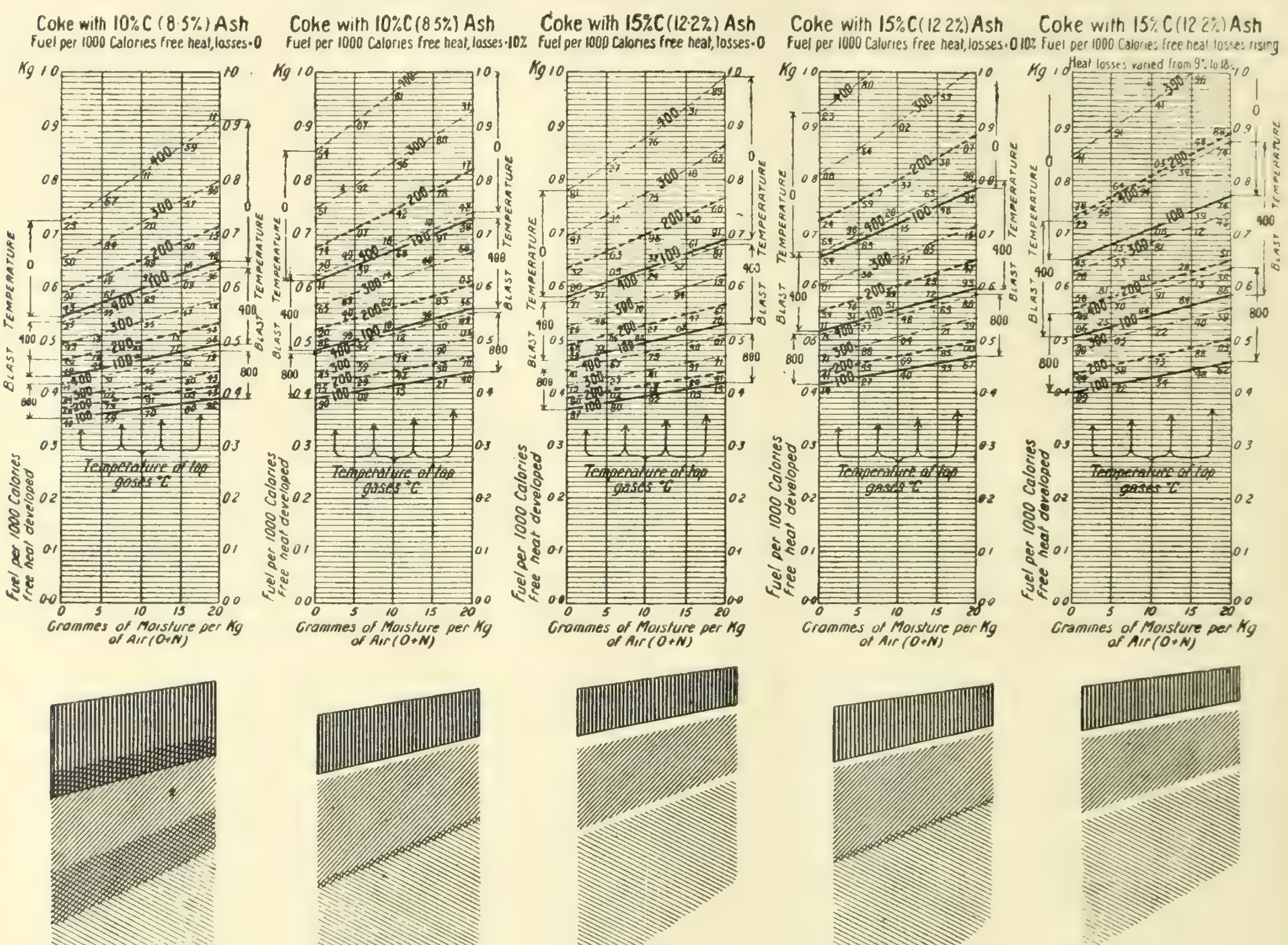
$$E_f = \frac{E_h \times F_h}{F_r + F_c + F_h + F_w}$$

and the proportionate amount by which the total consumption of fuel per ton of yield is lowered is greater the higher the previous rate of consumption.

Practical tests have shown that by reducing the moisture of the blast the smelting process is accelerated and the quantity of dust in the gas and the losses of material charged are reduced, this being the natural result of the lower velocity at which the gases escape. Gayley reported the same experience at the Etna works.

In practice the difference in fuel consumption, due to the different moisture conditions of the atmosphere in summer and winter, is not so great in modern coke blastfurnaces as one might expect. This is undoubtedly due to the fact that the furnaces are, as a rule, not well protected, and the radiation losses, which are at all times proportional to the time taken to reduce the charge, are higher in winter than in summer, and so more or less counteract the effect of the drier air.

INFLUENCE OF MOISTURE IN THE BLAST.



Apart, however, from other advantages resulting from drying the blast and having regard to the saving effected in fuel consumption alone, the values obtained show that, whereas the economical result of drying the blast in some instances is very remarkable, it varies considerably, and the question of introducing dry blast must be settled in each case on its own merits. The advantages are dependent in every case on local conditions, such as the dampness of the atmosphere and the cost and quality of the fuel. They are influenced besides by the kind of product, the quantity of output, the reduction period, and the type of furnace. Assuming that the condition of the atmosphere as regards moisture is high enough, the adoption of dry blast is certain to prove advantageous under the following conditions:—

(1) For blastfurnaces working with high blast temperature, and yet with high waste gas temperature, such as furnaces smelting ferro-manganese, ferro-silicon, or ferro-chromium.

(2) For blastfurnaces in localities where the atmosphere is particularly moist, such as on the coast, especially in southern countries.

In both these cases the advantages are unquestionable.

(3) For blastfurnaces which work with high fuel consumption and with waste gases at high temperature and produce pig iron, the composition of which requires careful control, according to the purpose to which it is destined, such as Bessemer pig, foundry pig, and high silicon pig generally.

In particular this would apply to furnaces insufficiently protected against loss of heat by radiation, especially small furnaces running for long periods.

The practical methods of effecting the removal of the moisture from the blast have gone through various stages of development and are still in process of evolution, but, as much has been written in the technical press from time to time concerning dry air installations, the author will confine himself to a few remarks only on this matter.

The freezing out of the moisture is now usually effected by stages, cold water being used for the preliminary drying and the process being completed by the old method. Combined processes, such as the use of a salt solution at low temperature, are also used, the preliminary and final drying being combined in one tower, by which some economy in first cost and in subsequent working is achieved.

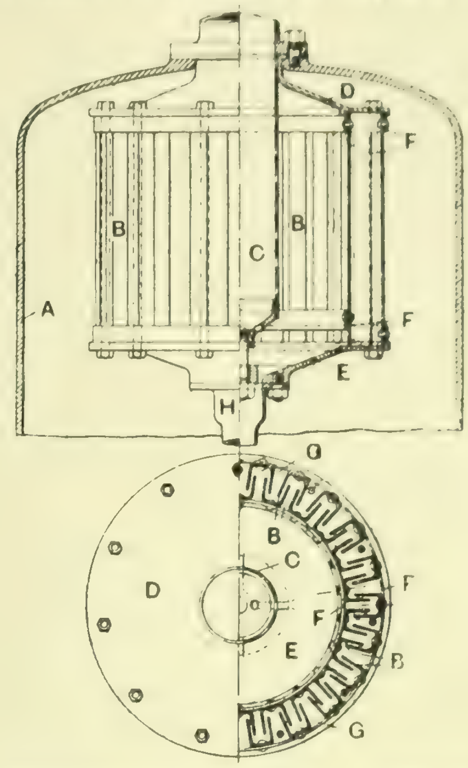
The system of Daubiné and Roy is of interest in that the drying of the blast is effected by chemical means using calcium chloride. The plant at the Differdingen Ironworks is reported to have given most satisfactory results in working, and the first cost was comparatively small. The author was, however, unsuccessful in his request for permission to visit this installation and also that on the Gayley system at the Deutscher Kaiser Works, at Bruckhausen. Both establishments declined to allow him to inspect their installation on the ground that they were not in operation at the time, and the last-named works gave as the reason of this that no advantage had resulted.

It should be mentioned that the heat which is absorbed in dissociating the moisture of the blast is restored to the waste gases through the combustion of the hydrogen resulting from the decomposition of the vapour, and this fact should be taken into account in cases where special arrangements have been made for the utilisation of the heat of the waste gases.

CAIRD'S STEAM SEPARATING AND PURIFYING APPARATUS.

In apparatus employed for separating impurities or extracting moisture from steam it has been proposed to employ a cylindrical casing in which are a number of vertical angular or trough-shaped strips integral or otherwise fixed and concentrically arranged, so that a portion of the steam entering the casing flows radially and directly inwards, through the open passages between the strips, to the end of a central outlet pipe, and a portion is projected against the strips on the surfaces of which are deposited the water, grease or other impurities carried by the impinging steam, which impurities pass down into a chamber below and thence to an outlet. In the apparatus illustrated herewith, the invention of Mr. E. B. Caird, of 777, Commercial Road, London, the parts are so constructed and arranged that all the steam admitted to the enclosing steam-tight casing from the steam boiler, while travelling radially inwards to an outlet pipe for the dry or purified steam has to take a circuitous or zigzag course between one or more series of baffles or slats, disposed substantially vertical, the baffles in each series being formed and arranged to present large surfaces to intercept the particles of moisture carried along by the steam down which surfaces these particles glide, eventually falling on a sloping floor communicating with a drain pipe leading to the lowest part of the steam generator or to a part well below the surface of the water therein, so that no vapour from the generator may find an exit through this drain or outlet pipe.

Referring to the illustrations, A is the steam dome communicating with the steam boiler; B denotes a series of baffles or slats arranged circularly around a central dry steam outlet pipe C. The baffles, which are of channel shape, are spaced apart and arranged in two concentric rows with their edges overlapping so that the steam, entering from the dome through the openings G left between the baffles of the outer row, is forced to take a zigzag path on its way towards the dry steam outlet pipe C. The wall of the dry steam pipe C is perforated for the admission of the dry steam which passes upwardly through the pipe to a distiller or other apparatus in communication with pipe C. The baffles are arranged with their ends abutting against top and bottom end plates D, E, and riveted to ring plates F, while the



CAIRD'S STEAM SEPARATING AND PURIFYING APPARATUS.

end plates are stayed by means of bolted rods. The end plates are formed to serve as bearings for and attachment to the dry steam outlet pipe C and a drain pipe H. The separator is suspended by means of flanges and studs from the top of the dome. The condensed particles impinging on the limbs of the baffles will be arrested and running down the limb surfaces will drop on the sloping floor constituted by the end plate E and escape easily by the drain H.

The Junior Institution of Engineers: Visit to Ghent Exhibition.—A week-end excursion, July 4th to 7th, has been arranged by this Institution to Brussels for the purpose of visiting the Ghent Exhibition. The party will leave London on Friday, July 4th, and visit the Exhibition on the Saturday. For the Sunday, excursions will be arranged, and on the Monday places of interest in Brussels will be visited, the party returning to London in the evening.

Iron and Steel Institute: Brussels Meeting.—The autumn meeting of the Iron and Steel Institute will be held in Brussels, on Monday, Tuesday, Wednesday, and Thursday, September 1st to 4th, 1913. The provisional programme is as follows: Monday, September 1st—Opening meeting in the Hall of the Palais des Académies. A selection of papers will be read and discussed. In the afternoon visits will be made to places of interest in Brussels. In the evening a reception will be held by the Burgomaster at the Hotel de Ville. Tuesday, September 2nd—Meeting in the morning for the reading and discussion of papers, at the Palais des Académies. Afternoon visits to Colonial Museum and the Parc de Tervueren. In the evening it is hoped that His Majesty King Albert will receive the members at the Royal Palace, Brussels. Wednesday, September 3rd—A special train will leave in the morning for Ghent, where a visit will be paid to the International Exhibition now being held in that city. Thursday, September 4th—Alternative excursions will be made to Liége and Charleroi. The Liége excursion will include a visit to the works of Messrs. John Cockerill & Co., Seraing, to the works of the Ougrée-Marihaye Company, and to the Coppée Coke Oven Gas Plant at Athus-Grivegnée. The excursion to Charleroi will embrace visits to various metallurgical, glass, and other works in the vicinity of that town.

SOME FUNDAMENTAL FAULTS OF PRESENT-DAY FURNACES AND THEIR REMEDIES.*

BY ALLEYNE REYNOLDS.

PRACTICAL success in the working of furnaces demands knowledge both of human nature and, to coin a new expression, of furnace nature. The latter admits of more easy understanding than the former. The most successful practical management depends on the manager possessing, as far as possible, a knowledge of the fundamental laws of nature, and also that highly-developed power of observation of facts possessed by skilled men of the working class. Unfortunately, the double qualification is very rarely fully developed, or evenly balanced in the managerial class, whilst the two most extreme types of useful individuals, both of whom depend on analytical methods of trial and error, are governed by

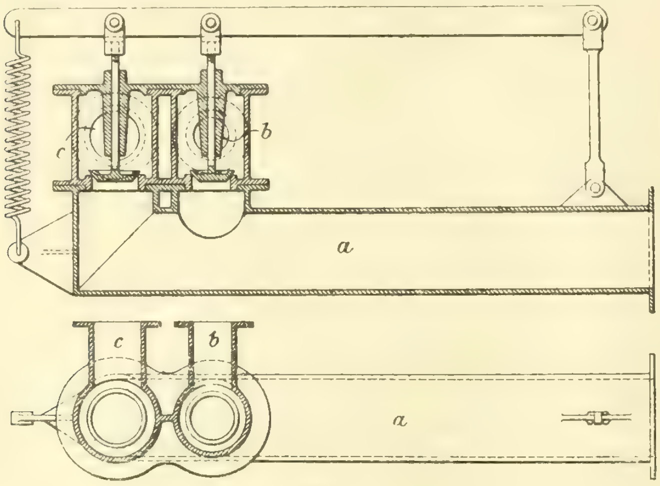


FIG. 1.

antagonistic obsessions, the working class being very much hampered by erroneous preconceptions as to the laws of nature, and the ultra-experimental scientific class sometimes drawing wrong conclusions from lack of knowledge of the observed facts in the large-scale laboratory of practical manufacture.

When managing one of the most important batteries of steel-melting furnaces in the world, the author felt at the same time that more real and solid knowledge of the fundamental laws of nature and their operation would much aid him in better work, but the nature of his occupation left him little time for abstract study. He felt, in face of his daily observation of facts, that much book knowledge was erroneous and had filled his mind and that of others with obsessions which it was desirable to remove.

Since then, he has had some leisure for such study, and during the period much valuable work has been done by thermo-chemists and other physical chemists which has much assisted him; but he has only finally quite cleared his mind by adopting the inverse mental method to that generally employed, and by means of synthetical methods of reasoning been able to avoid the pitfalls of analytical methods. He will, therefore, adopt this method in the present paper, in spite of the fact that he must traverse much well-known ground, but the reiteration will, he thinks, be held to be justified, when it is seen how this synthetical method of reasoning could have saved much costly practical experience, and how many workmen's methods are justified thereby. The principles of combustion being the very foundation of the subject matter of this paper, they will be briefly dealt with at the outset.

Principles of Combustion.—The precise law which decides how great a change of heat has to be imparted to two chemical reagents, in order to initiate reaction between them, is not known at anyrate to the author. Its nature, however, is obvious. The reaction when initiated requires for its spontaneous continuance a certain ratio between the heat of formation of the products of reaction, and the heat of ignition of the reagents dependent on the rate of conductivity of heat in the reacting substances. In order to illustrate the nature of the essential conditions, the following method of explanation, which, although confessedly very crude, forms a useful aid to one's understanding of the nature of the governing conditions, has been adopted.

Picture a cube composed of a mixture of mutually combustible gases in chemically equivalent proportions, surrounded by 26 cubes of equal size, the whole forming a cube three times the dimensions of the interior cube. Imagine, in the first place, the 26 outer cubes to be absolutely non-receptive of heat, and that, by some means, it is possible to impart heat to the interior cube until its contents, say, $2X + 2Y$, are brought to ignition temperature, a quantity of heat A being required for the purpose. Imagine, on the (explosive) chemical reaction taking place, that it results in complete chemical reaction, B calories being necessarily evolved. The total charge of heat in the products would be that required for the complete dissociation of the products into the original substances at ignition temperature. Clearly, then, only partial association could take place, indicated by the equation

$$2X + 2Y = XY + X + Y,$$

in which X and Y are used as chemical symbols and not as algebraic. Now, by adding to both sides of the equation a neutral substance Z, sufficient absorption of energy might occur to allow of the reaction proceeding further, according to the equation

$$2X + 2Y + Z = 2XY + Z,$$

but a larger charge of ignition heat than A would be required to bring the whole to ignition temperature. There is nothing to prevent Z being partially or wholly replaced by X or Y, or both. In conducting ordinary analyses, temperature is not allowed to rise to an important extent, hence chemically equivalent amounts of reagents have a chance of full inter-reaction.

The above is an explanation of a well-known truism, namely, that in general an excess of reagents is required to bring a desired chemical reaction to completion. It will be seen to be purely physical, and not wholly dependent on lack of opportunity for the reagents to come in contact with each other, as is, to the author's knowledge, frequently supposed. In the case of combustion of most fuels with air, the full amount of the diluent Z is apparently not provided by the nitrogen of the air, and some surplus air even is required. To show that this has sometimes not been fully enough realised by some, the author would direct attention to the attempts that have been made to obtain super-oxygenated air which for many purposes would be of no use when obtained.

Reverting to the interior cube, imagine next the surrounding cubes to be composed of the same substance as the interior cube, but the rate of conduction to be equivalent in mean effect in a given time to that which would be the case if the conduction of heat was perfect along the half dimension and there ceased altogether. It will be seen that unless $B = 12A$, ignition would not spread from the inner to the outer cubes. Now, in the case of the reaction

$$2C + 2O = 2CO \text{ or } CO_2 + C,$$

the ratio of B to A in the latter is much greater than in the former case, and hence at low temperatures the latter reaction takes place. Here we have a clear picture of the typical reaction of the gas producer.

The surplus energy due to the equation $2C + 2O = C + CO_2$ provides more than ignition energy for the next batch of $2C + 2O$, and in the result, the equation of the gas producer is somewhat of the form

$$x(2C + 2O) + y(C + CO_2) = 2(x + y)CO$$

in the upper zones. So long as reaction is proceeding, so does temperature rise. Owing to this, slags may be formed in the upper zones of the producer which, on descending into the cooler zones, become solidified and scaffold. The author perceived this, to a large extent, in 1897, and wrote a letter to "Engineering" on the subject. Although it drew no correspondence at the time, it is now recognised that CO is largely produced direct in the gas producer.

When freed from the erroneous impression that CO can only be produced by reduction of CO_2, we are in a position to understand why a flame can be produced in a direct fired furnace, burning coal or coke. Locally, jets of air pass through gaps in the fire, whilst also, in certain smaller gaps, C is burnt direct into CO_2, according to the equation

$$(a) \quad C + 2O = CO_2.$$

* Paper presented at the annual meeting of the Iron and Steel Institute, May, 1913.

In others, the ultimate gas producer reaction takes place

$$(b) \quad C + O = CO.$$

The unburnt air which has passed through the fire reacts with this and produces flame according to the equation

$$(c) \quad CO + O = CO_2.$$

It matters not whether CO_2 be formed direct according to the equation (a), or in two stages, according to equations (b) and (c). In like manner, it matters not whether a hydro-

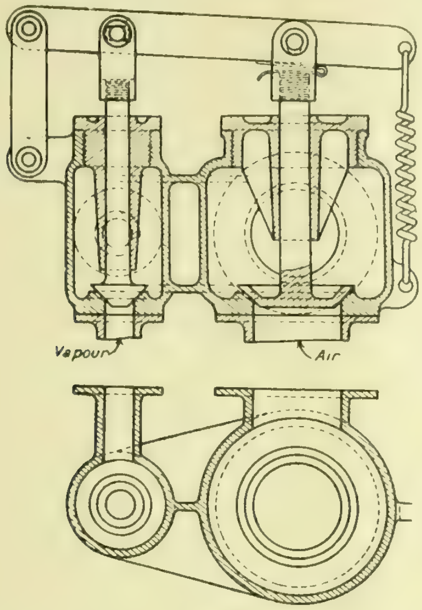


FIG. 2.

carbon, say, CH_4, has been distilled off and then burnt into $CO_2 + 2H_2O$, or decomposed into $C + 4H$ and then burnt.

If steam be added to the air, it is a mere diluent. It will be decomposed and recomposed, and represent waste and lessened calorific intensity. A definite advantage, however, arises from securing the combustion in two stages, as the second stage may be made to take place wholly in the charge chamber of the furnace if desired.

By employing a deep bed of fuel, and maintaining it at constant depth, a producer gas of fairly constant composition is generated. In common practice it is left to the skill of the furnaceman to supply the proper quantity of air to burn the producer gas. Even supposing it were possible for a trained eye to allow him to do this, natural causes would place it beyond his power (to an extent which the author feels is underrated), giving rise to great and harmful wastage of fuel.

According to variations in the direction, and pressure of gusts of wind, the variations in amounts of air admitted at natural draught air inlets are far too serious to give even a good furnaceman a fair chance of regulating the air supply. Merely securing correct average is not enough. The author recently made some practical tests of the amount of air entering the air reversing valves of some old-fashioned Siemens crucible-steel melting furnaces. During succeeding quarter minutes the air entering the valve varied between the rates of 350ft. and 500ft. per minute, the gusts of wind being no greater than 20 miles per hour. On a smaller furnace he found that by using or not using wind-screens in front of or behind the air valve, according to the direction in which the reversing flap was turned in relation to the direction of the wind, the mean air entering the valve was halved or doubled. In this case 180ft. per minute was the air desired. The gusts of wind lowered it to 70ft. on one side, and raised it to 350ft. on the other. Forced draught, duly throttled, was then installed, and this steadied the air supply. No workman can be expected to overcome such conditions by his skill; it is not fair to expect it of him.

Coal may be regarded as a solid composed of hydrocarbons, which may be volatilised by heat, and solid (non volatile) carbon, which may be gasified by semi combustion into CO. The products of the ultimate combustion of coal are mainly CO_2 and H_2O, and it has been shown by actual experiments that for most coals the gases of combustion only are void of CO, if the ratio of CO_2 to O_2 (by vol.) be 10 to 3. This proportion will then be secured if, by suitable means, about 40 per cent. of the total air used is passed through the producer as primary air, and about 60 per cent. through the furnace as secondary air. Before proceeding to describe his own method of securing this, the author will first point out one or two obviously incorrect practices he has known to exist.

He has been shown regularly-taken analyses of producer gases, coupled with calculations of the combustible value of the gases per unit volume, without the temperatures at the producer accompanying them, or analyses of the products of their combustion. Such data are almost worse than useless. A unit weight of coal completely burnt into given products of combustion has a given calorific value. At every stage of progress towards complete combustion calorific value is being changed into sensible heat, and the sum of sensible heat and calorific value is a constant in the absence of heat absorption. The richer the gas, the more air required to burn it; the poorer, the less air. The chimney products of complete combustion and their maintaining constant composition afford the main index of theoretical and practical good working.

The Author's Devices for Securing Correct Complete Ultimate Combustion. — In the case where coal or other solid fuel is employed, the author's device takes the form shown in Fig. 1. A chamber (a) connected to a source of high-pressure air has two closed branches (b) and (c), the branch (b) being provided with connections to the air inlet of the gas producer, and (c) with the air inlet or inlets of the furnace. The connections between chamber (a) and branches (b) and (c) are provided with valves and seatings, the diameters of the latter being such that their areas are proportional to ratios of primary and secondary air supplies required.

The valves are mounted on a common lever, the distance of their connections from the fulcrum being in the same ratio as the diameters of their seatings. They are loaded by a spring to an extent that the pressure required to open them is so large a multiple of any resistances encountered, that the latter become practically negligible quantities; hence at all times practically constant ratios of primary and secondary air are passed through the valves.

In the case where liquid fuel is employed the device takes the form shown in Fig. 2. The valves are so proportioned as always to pass the correct ratios of gaseous fuel and air through them (say, 1 to 9). The smaller valve seating is connected to a vaporising apparatus, the larger to a source

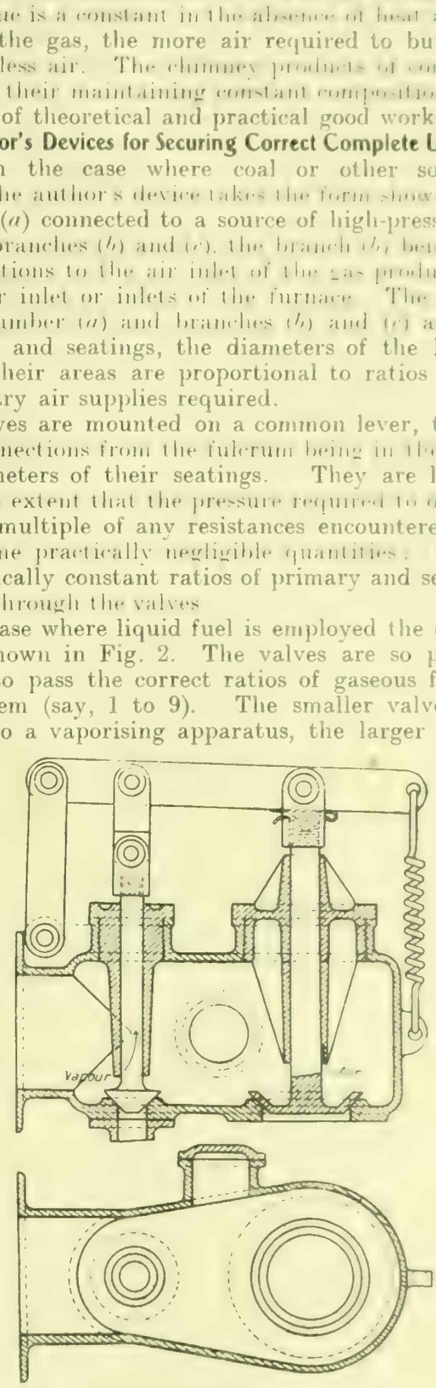


FIG. 3.

of air at the same pressure as the vapour. Thus at all times correct ratios of vapour and air are delivered to the furnace. The manner in which the constant relative pressure of vapour and air is secured is simple.

The vaporiser is made of materials capable of withstanding any temperature it is likely to be exposed to, and its heating surface is provided so as to be in considerable excess of any requirements. Its general type will be that of the pipe stoves used to heat the blast for blastfurnaces, but the fuel will enter the pipes.

By putting the stock of fuel in an air vessel, under the same pressure as the air supply of the furnace, and maintaining the heating surface of the vaporiser always in excess of requirements, the amount of liquid fuel which enters the vaporiser is only that which requires contact with the amount of heating surface it is exposed to. Hence fuel is only vaporised at the rate it is consumed. Fig. 3 illustrates the

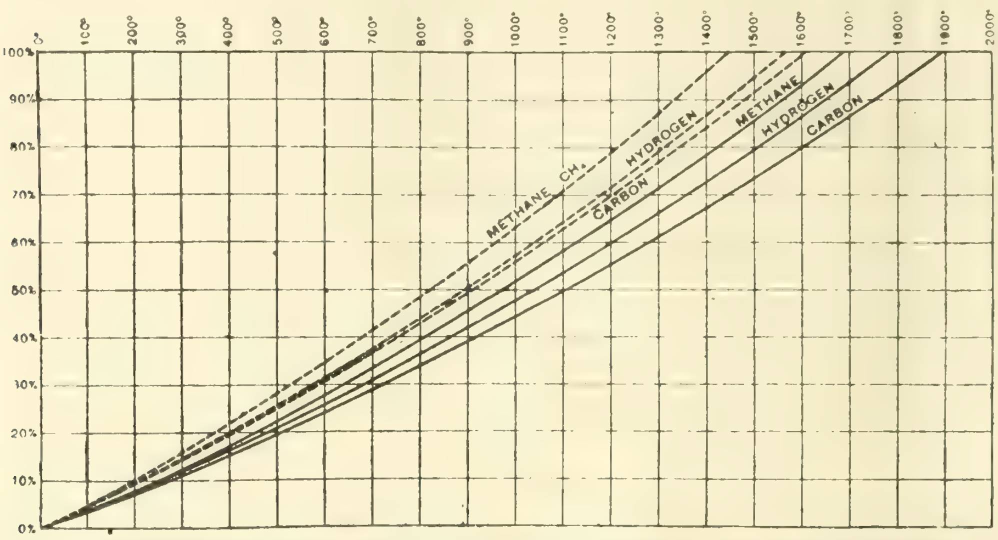


FIG. 4.—DIAGRAM SHOWING PERCENTAGES OF HEAT DEVELOPED CONTAINED IN PRODUCTS OF COMBUSTION OF CH_4, H_2 AND C_2 WITH AIR.
The full lines relate to products of complete combustion (assumed to be possible) with chemically equivalent amounts of air, and dotted lines to products of combustion with 30% excess of air.

valve system as modified in the case of an internal-combustion engine.

The Regenerative System.—The products of combustion of a furnace, of course, cannot issue from the combustion chamber at a lower temperature than the heated charge. The temperatures demanded in steel-making are almost as high as the complete combustion of carbon by cold air admits of, even in the absence of heat absorption, whilst the high specific heat of H_2O vapour in relation to its heat of formation, and the large amount of energy required to volatilise the hydrocarbons in coal, result in sufficiently high temperatures for that purpose being unattainable by means of combustion of coal with cold air. In spite of this, many people are still dazzled by the high calorific power of a unit of CH_4, forgetful of its cost and low efficiency for heating purposes. The relative efficiency values of CH_4, H_2, and C_2 are set out in Fig. 4, the text beneath which explains itself.

By intercepting heat from the products of combustion and imparting it to the constituents of combustion, more of the heat of combustion becomes transmissible from the fuel to the object to be heated. In a regenerative or recuperative system, if the course of the outlet gases being cooled and the inlet gases being heated were the same, only equilibrium of temperatures could be arrived at between them. When the outlet and inlet gases are made to traverse the system in opposite directions, practically the whole energy of the outlet gases not otherwise employed might be transferred to the incoming gases. But as the sensible heats of H_2O and CO_2 are at high temperatures, in excess of the sensible heats of their constituents at such high temperatures, this excess heat is unavailable for regeneration.

The author knows by experience that some people do not appreciate the fact that a regenerative or recuperative system is capable of heating the gas and air passed through it, to as near the maximum temperature obtaining within it as the relative surfaces and conductivities of the gases and regenerators or recuperators admit of. Suppose a section of such a system to be capable of cooling the outlet gases from a temperature of 2° to a temperature of 1° by imparting a temperature of 1° to the inlet gases. Obviously, then, a superposed section is conceivably capable of cooling outlet gases from 4° to 2° and heating inlet gases from 1° to 3°. By superposing sufficient regenerators of this sort the inlet gases would clearly always be 1° cooler than the outlet gases at all points. It is at once obvious that no direct economy can possibly result from the employment of regeneration to the combustible gas. To the exact extent of the sensible heat of the gas the cooling down of the outlet gases would be prevented, for the outlet gases could not be cooler than the inlet gases. Hence it may be seen that the use of gas regenerators in the case of producer gas in theory reduces the potential value of the fuel by the difference between the calorific power of the reaction $C+2O=CO_2$ and that of the reaction $CO+O=CO_2$, in respect of the fixed carbon contents of the coal.

On the other hand, unless absorbed otherwise, the products of combustion issuing from the furnace to the regenerators must contain more energy than that utilisable to heat the secondary air. Owing to this the only way to utilise any such unused balance is to employ it to heat the air blast of the producer.

The author understands, on the authority of a French metallurgist, that in France a very useful and logical discrimination is made between the words "regenerator" and "recuperator," the former denoting a reversible system and the latter a continuous system, and for the purposes of the present paper he will employ the words in question in the sense indicated. In an ideal recuperative system the maximum temperature of the recuperators cannot be less than that of the charge in the furnace to which heat has been transmitted. In a regenerative system, however, the mean maximum temperature may be much less.

Taking a regenerative system and assuming a unit of fuel to be burnt between each reversal in an empty furnace, ideal as to absence of radiation and loss in waste gases, the stock of heat in the regenerators at the end of each reversal period would progress in the following manner, starting by using the right-hand chambers for waste gases:—

Reversal.	—	1st.	2nd.	3rd.	4th.	5th.	6th.	7th.	8th.
Left	0	2	1	4	3	6	5	8	7
Right	1	0	3	2	5	4	7	6	9

After a large number of reversals the temperature drop between reversals will become only a small percentage on the temperature. Losses of energy occurring in practice, and for the reasons given as to heat in products of combustion taking

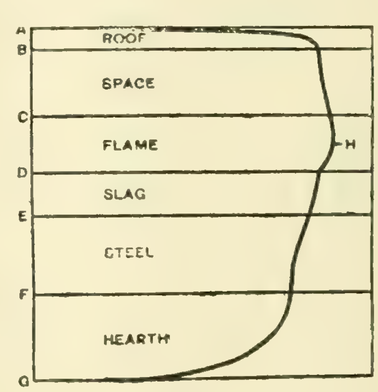


FIG. 5.

place from high temperatures being unavailable, the regenerators cannot readily be got to quite as high average maximum temperatures as the waste gases issuing from the furnace to them.

Now, the surfaces of the ports and conduits from the valves to the regenerators, and from the regenerators to the furnace, are so small that they may be very rapidly exposed to changes of temperature, and may be disregarded as efficient regenerators in practical calculations; but for the very reason of their small heating surface, their maximum temperature may be lowered by very frequent reversals. When a skilled melter perceives that he has overheated the ports of his furnace he at

once—though not fully understanding the reason—proceeds to reverse the valves of the furnace very frequently. The conditions bear some relation to what occurs if a unit of water at, say, 80° C. be poured through a long tube into a vessel containing, say, 100 units of water at 60° and then aspirated back again. There will be a sudden temperature drop in the unit of water at 80° as it meets the 100 units at 60°, and on reversing the action there will be only a minute rise of temperature of the unit of water as it passes back through the tube.

As steel melting furnaces furnish an example of regenerative furnace in which the temperature requisite for the charge to attain so closely approaches the limit of temperature endurance of the materials admissible for furnace construction, they afford the most instructive subjects of study.

Heat transference conditions are rapidly rendered inferior as the charge becomes fused, and it is at this important stage we will study it. At this stage the conditions become wholly different to those in a crucible furnace. In the latter almost the whole surface of the crucible is heating surface, and the contents thereof may be superheated by a flame of very little higher temperature than that of the charge in the crucible. In the open-hearth furnace, on fusion of the charge, the heating surface of the latter becomes less than the surface radiating heat from it.

The conditions governing the transference of heat are well illustrated by Fig. 5, which clearly shows the character of the temperature gradient of an open-hearth furnace. This temperature gradient has been drawn in view of the fact that the metals and carbon decrease in conductivity with rise in temperature, and in general the oxides, especially the basic oxides, at a certain point rapidly increase in conductivity with rise of temperature. In Fig. 5 the ordinates represent temperatures, whilst the co-ordinate represents a section through the furnace hearth, steel, slag, flame, air space, and roof. A B is the roof, B C the space between the roof and flame, C D the flame, D E the slaglayer, E F the bath of steel, F G the hearth, and H the hottest portion of the flame. The temperature at D must be high enough to enable that at F to be a casting temperature for the steel, that is, quite 1,550° C. for a mild steel. The temperature at B must be below that which will fuse or otherwise damage the roof. This can therefore hardly exceed 1,780° C. for materials generally available for the purpose. The former condition involves a higher temperature than 1,550° C. at E, and a still higher temperature at D, which, in consequence, may require to be even 1,700° C.

At some point in the flame a still higher temperature may be involved, say, as much as 1,800° C., and the fall of temperature between this maximum point H and B must be sufficient to prevent that at the latter point being too high. These close limits then demand that combustion shall progress at so even a rate that at all points D, of the heating surface of the slag, heat absorption and temperature are uniform. This in turn involves that the temperature of the flame at its immediate entrance into the furnace shall be of full intensity. The curve D E F may be, and is, modified somewhat in ordinary practice by various catalytic actions, which aid ordinary processes, but unfit them for the production of steel deoxidised and dead melted in like manner to crucible steel. This very defect, however, alone renders practicable the basic process with its deep layer of slag, and the same remark applies, but perhaps in less degree, to the acid process.

(To be continued.)

Third International Congress of Refrigeration.—A pamphlet has been issued giving the particulars of this Congress, which is to be held at Chicago in September next. It will be divided into six sections, dealing with: (*a*) Liquefied gas and units; (*b*) the design, construction, operation, and method of testing refrigerating machinery and insulating materials; (*c*) the application of refrigeration to foods; (*d*) the use of refrigerating apparatus in the industrial arts; (*e*) refrigeration in railway and steamship transportation; (*f*) questions relating to legislation and administration. The Secretary-General is Mr. J. F. Nickerson, 431, So. Dearborn Street, Chicago. The first Congress was held in Paris in 1908, and the second in Vienna in 1910.

IMPROVEMENTS IN INTERNAL-COMBUSTION ENGINES.

A RECENT patent granted to Mr. J. H. Hamilton, Sandiacre, Derby, relates to single acting engines having trunk pistons working in cylinders with their front ends open to the crank race in the bed and is applicable to engines with two or more cylinders placed side by side, the pistons being coupled to cranks on the same shaft. For two-cylinder engines cranks are used at 180° to one another, for three-cylinder engines cranks at 120°, and for four-cylinder

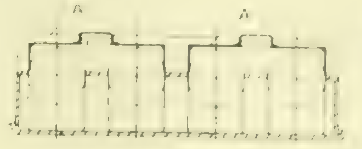


Fig. 2.

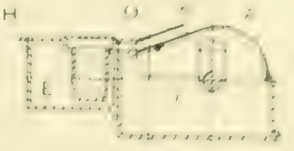


Fig. 1

engines, two cranks on the same centre and two others at 180° to them as usual in multiple crank engines. In a two-cylinder engine one oil guard made of sheet metal is fixed over the two cranks and fitting to the bed so as to completely enclose the cranks and reciprocating parts. A hole is however made in the top of this oil guard at the end next the cylinders and between the latter, and a hood or bridge piece is fitted over this hole and extends beyond its forward extremity, thus forming a passage whereof one end opens to the atmosphere and the other to an air duct formed in the bed and leading through a silencer placed in the cylinder jacket casting to the air ports of the cylinder admission valves. Thus the air drawn in by the pistons to form the explosive charge goes through this passage and carries with it such smoke or fumes as may rise through the opening in the oil guard. Baffle plates are placed so as to prevent oil being splashed into or below the opening in the oil guard, thus the fumes are kept out of the engine house. In a three-cylinder engine the construction is similar but the oil guard covers the three cranks. In a four-cylinder engine two oil guards are used, viz., one over each pair of cranks as described for the two-cylinder engine.

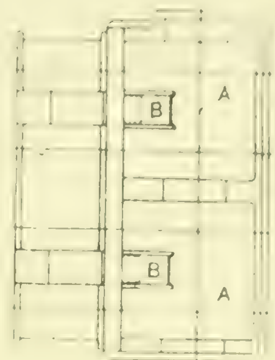


Fig. 3.

Improvements in Internal-Combustion Engines.

Fig. 1 is a longitudinal section through the engine bed and the cylinder jacket casting. Fig. 2 a cross section through the bed on the line XX, Fig. 1; and Fig. 3 a plan, the engine shown being a four-cylinder one. The oil guards A cover two cranks and by fitting against the end as shown at J, enclose the space in which the cranks and connecting rods work completely. The air supply to the cylinders enters through the hood B, and passing through the silencer E goes through the passage H to the cylinder. An opening O in the top of the guard A allows fumes escaping from or past the piston to escape into the hood B and therefore to be drawn back into the cylinder along with the air.

North-east Coast Institution of Engineers and Shipbuilders.—Upwards of two months ago the Council of the North-east Coast Institution of Engineers and Shipbuilders decided, after much deliberation, to form an Aeronautical Committee, it being considered that the study of aeronautics might advantageously be coupled with that of engineering and shipbuilding. At the same time negotiations were entered upon with the North-eastern Aero Club, with the result that that body has now become absorbed in the Institution. The committee is largely representative of the club that was, and the names are as follows: The Hon. Sir Charles A. Parsons (chairman), Messrs. J. Duncan Hodgson, J. H. Holmes, J. Cusworth, and C. S. Vesey Brown, Prof. Henry Stroud, Colonel R. Saxton White, Messrs. Gerald Stoney, J. Mitchell Moncrieff, A. H. Law, and C. Ian Burrell. The objects of this committee, among others, will be to arrange meetings for the discussion of aeronautical questions, and generally to promote the study of such among the members of the Institution.

PETROL-ELECTRIC MOTOR-VEHICLES.*

BY J. B. G. DAMOISEAU.

THE system of traction in which the electrical energy required for propulsion is generated on the vehicle itself, was applied for the first time 20 years ago by Mr. J. J. Heilmann. The first locomotive on the Heilmann system, "La Fusée," which was tried in 1893-94 on the system of the Chemin de fer de l'Ouest between Le Havre and Beuzeville, and later between Paris and Mantes, consisted of a boiler of 145 square metres heating surface, feeding a horizontal, compound, balanced steam engine, with fixed cut-off and variable speed. This engine, which generated 600 b.h.p. at 360 revs. per minute, was direct-coupled to a separately-excited continuous-current generator. The excitation at constant pressure was provided by a special machine driven by a steam engine. By increasing or decreasing the excitation of the generator, the speed of the steam engine was decreased or increased in proportion, and in consequence also the power supplied to the eight electric motors which were fixed on the four axles of each of the two bogies.

As a result of the tests carried out with this locomotive, two more were built on the same system, but of greater power, each being provided with a vertical steam engine of 1,350 i.h.p. at 400 revs. per minute, direct-coupled to two generators, one at each end, which supplied the electrical energy to the eight motors. These locomotives were tried on the same railway system in 1897-98 between Paris and Rouen. Each of these two locomotives was constructed in such a way that it could be driven in either direction without being reversed at the terminus, and had a tender attached. One of these tenders was fitted with four electric motors, to which current was supplied from the generators on the locomotive.

The method of control employed on these Heilmann locomotives is very elastic, and has the further advantage of being economical in two respects. From the thermal point of view, the steam consumption per horse-power hour is remarkably constant, as the point of cut-off is fixed. From the electrical point of view, the whole of the electrical energy generated is, with the exception of the losses in the field rheostats, usefully employed for traction. This system, in which the vehicle carries its own electrical generating plant, was subjected to considerable criticism at the time of its introduction, and it is only due to the development of automobiles and the internal-combustion engine, as well as to progress in electric traction and the practical demonstration of its advantages, that the above system of traction came into favour again in its new form as the petrol-electric vehicle.

THE VARIOUS PETROL-ELECTRIC SYSTEMS.

A number of systems, employing continuous or alternating-current transmission, either partially or wholly, have been proposed for automobiles running on the roads, with the view of remedying the inherent inconveniences arising from the use of clutches and the necessity of frequently varying the speed of such vehicles. Some of these systems in practice do not seem in general to have given the results expected of them.

Of the various heat engines capable of application to automobiles running on rails, the internal-combustion engine using liquid fuel—petrol or benzol—is the only practical type. Continuous current is likewise universally employed. The design adopted for motor-vehicles using internal-combustion engines is necessitated by the limitations of these engines. Thus, as internal-combustion engines are unable to start under load, means must be provided for starting them light. Moreover, such engines give a practically constant torque, and to be economical should run at a speed below that corresponding with maximum power so as to prevent the engine being pulled up; but as they must operate somewhere near that critical speed, it follows that it is essential to introduce gearing between the engine and the axles so that the speed of the car can be varied whilst that of the engine remains uniform.

There are thus three methods of transmission: (1) Mechanical gear; (2) electrical transmission gear; (3) a combination of mechanical and electrical gear.

As, however, the internal-combustion engine can work either at constant or variable power (by regulating the admission of the fuel), and the power required for traction is also variable, it follows that two distinct methods may be considered: (*a*) An arrangement comprising a means of storing energy and for dealing with the fluctuations in the demand for energy whilst the engine generates constant output. This method has the advantage of allowing the energy to be stored which is produced when the car runs down gradients, and whilst braking. (*b*) An arrangement in which energy is not stored, and in which the engine supplies the power necessary for driving the vehicle.

Thus each of the above three methods of transmission, mechanical, electrical, and mixed, can, if desired, have incorporated with it the storage of energy. To complete this enumeration of possible automobile systems using internal-combustion engines, it remains to be said that if energy is stored this can be done either in the form of kinetic energy, a flywheel being used, or as potential energy, electric accumulators then being employed.

This brief résumé shows the large number of types of internal-combustion automobiles which are theoretically possible. As a matter of fact, there are at the present time automobiles with internal-combustion engines and mechanical, electrical, and mixed drive; but those with the mixed drive are the only ones in which accumulators are utilised. The present paper deals with motor-cars with internal-combustion engines and with electrical or mixed drive. These cars are usually known by the general term of petrol-electric vehicles, although petrol need not be the only fuel used. The majority of the petrol-electric vehicles built comprise essentially an internal-combustion engine driving a continuous-current generator giving a variable pressure; this generator supplies the electric motors driving the car axles. For the control a special controller is employed. In certain cases cars are fitted with two cabins, from either of which the car may be driven in either direction. The details and position of the electrical gear distinguish the different types of this class of car.

MOTOR-VEHICLES OF THE SOCIÉTÉ ANONYME DE LOCOMOTION ELECTRIQUE.

In 1904-1905 the Société Anonyme de Locomotion Electrique, owners in France of the Heilmann patents, built a petrol-electric vehicle to demonstrate its practical value. The wheel gauge was 1 metre, and the electrical gear, suspended on girders attached to the frame, was situated between the two bogies and beneath the floor of the car, only the cylinders of the engines protruding. This arrangement was chosen on account of that adopted on automobiles, the engines of which work without being under the direct supervision of those in charge.

The petrol engine with six vertical cylinders, each of 140 mm. internal diameter and 160 mm. stroke, and running at 700 revs. per minute, was direct-coupled to the generator and the exciter, both on the same shaft. The generator, which could give any pressure from zero to 550 volts, supplied current to the two electric motors; these drove through pinions the two extreme axles of the two bogies—each bogie had two axles and wheels of unequal size. The exciter was compound wound to give a pressure of 110 volts. The car had two cabins, situated one at each extremity of the platform of the car. In each cabin was fitted the following switchgear: A special controller with two handles, allowing the car to be driven in either direction, the connections for the series-parallel grouping of the motors, the rheostat for varying the exciting current of the generator, the electric-emergency brake, the measuring instruments and safety apparatus, a valve for the compressed-air brake, and a hand brake. The air for the brake was supplied by an air compressor driven from one of the axles to which a motor was not attached. This compressor was fitted with an automatic pressure regulator.

The two tanks containing the liquid fuel were placed on the two platforms. The two tanks containing the water for cooling the engine (the circulation of the water being entirely thermal) and the radiator for cooling the water were lodged on the roof of the car. Owing to the quantity of water contained in these reservoirs it was possible to cool the engine effectively when the car was on a gradient, the speed of the car being sufficient to bring about the rapid cooling of the water by the radiator. The silencer was fixed to the girders carrying the electrical apparatus. The engine, which was fitted with

* Paper presented at the joint meeting of the Institution of Electrical Engineers and the Société Internationale des Electriciens, Paris, May 21st–24th, 1913.

mechanically-operated valves, water cooling, a float carburetter, and a high-tension magneto for ignition, was started up by hand by means of a handle attached by gear to the crank, which revolved at constant speed whilst the car was in service. A centrifugal governor, acting on the admission valve, limited the speed of the engine to 700 revs. per minute.

The driver, standing in his normal position, could reduce the speed, and consequently the fuel consumption, whenever the car stopped, or when it was running light, by means of a flexible wire attached to the admission valve. Once the petrol engine was started up, it was sufficient, in order to start the car and to regulate its speed, to vary the excitation of the generator. This system of regulation by means of separate excitation has the advantage of producing the electric energy required for propelling the vehicle without absorbing any energy in rheostats; and consequently it has the advantage of obtaining economically, if desired, all draw-bar pulls and speeds possible without overheating the dynamos.

A car built for a maximum speed of 30 km. per hour had the following dimensions:

	Metres.
Distance between the axles of the bogies	8
Wheelbase of each bogie	1·5
Length of the car body	11·8

This car had a baggage-van in the centre of the coach between its two compartments, one of which was first class, the other second class. Access to this van was obtained from two platforms situated between the two compartments and the driver's cabins at each end of the car.

Motor-vehicles of the North-eastern Railway Company.

At about the same period trials with motor-vehicles were being carried out in England by the North-eastern Railway Company, the electrical plant being placed in one of the driver's cabins at the extremities of the car. The 80 h.p. petrol engine, with four horizontal water-cooled cylinders each of 216 mm. internal diameter and 254 mm. stroke, drove at a speed of 420 to 480 revs. per minute a 55 kw. continuous-current generator which supplied current at any pressure between 300 and 550 volts. The exciter, fixed above the generator, was belt driven. This shunt-wound exciter was also used to charge a 120 ampere-hour battery of accumulators used for lighting the car and for starting the petrol engine. The two motors, totalling 55 h.p., were fixed on a bogie beneath the generator.

The controller was of the ordinary type for series-parallel working, and was used for varying the speed and for operating the brake. A rheostat near the controller allowed the driver to vary the pressure of the generator. The electro-magnetic brake fitted to this car consisted of two electro-magnets suspended between the wheels of each bogie above the rails. When the brake was put on, the electric motors operated as generators, supplied current to the windings of the brake, producing in that way the adhesion of the brakes to the rails and also absorbing the energy generated by the motors.

An electrically-controlled air compressor supplied the air for working the whistle. A fan, belt driven from the exciter, cooled the radiator, which was situated on the roof. The procedure for starting the car was as follows: The petrol engine having been started by means of the battery of accumulators, and having reached its normal speed, the excitation of the generator was adjusted so as to obtain a pressure of 400 volts. The circuit between the generators and the two motors was closed, whilst the excitation of the generator was gradually increased by cutting out resistance until a pressure of 550 volts was obtained. The petrol engine was constructed by the Wolseley Tool and Motor Car Company, and the electrical equipment was supplied by the British Westinghouse Electric and Manufacturing Company. This car, of which the length between the buffers was 15·6 metres, had seating accommodation for 52 passengers, weighed in service 35 tons, and could reach a speed of 58 km. per hour.

Motor-vehicles on the Dion-Bouton System.

The two cars just described were in reality only test cars to prove the practical value of this form of traction. The first exploitation of petrol-electric motor-vehicles dates back to the years 1905-1906, and was undertaken by the Hungarian Arad Osanad Railway. This railway system has normal gauge and a length of 400 km. It was worked at first, as far as the passenger traffic was concerned, with 36 petrol-electric cars of two types. Those destined for slow trains had each a petrol engine of 30 h.p., and those for fast trains a 70 h.p. engine. The petrol engines and the generators of all these cars were supplied by the Société de Dion-Bouton.

As traffic had increased in consequence of the introduction of this kind of traction, the railway company was induced, so that trailers could be added, to increase the equipment from 30 h.p. to 40 h.p. It was found essential to increase the power still more. A Hungarian firm, a branch of the Société Westinghouse du Havre, was asked to undertake this transformation, which is still being carried out. When this transformation is finished, this company will own petrol-electric cars on two systems and of three powers—those on the Dion-Bouton system of 70 h.p., and those of the Westinghouse system of 60 h.p. and 90 h.p. As the transformation of these cars is not yet finished, the cars at present in use are of two types, but of four powers—40 h.p. and 70 h.p. (Dion-Bouton) and 60 h.p. and 90 h.p. (Westinghouse). This is at present the most important application of this kind of traction in Europe. The service is carried out by these 36 petrol-electric cars along with 4 steam motor-cars by Ganz with Dion-Bouton boilers, and 44 steam locomotives hauling "mixed" trains and goods trains.

The Dion-Bouton cars have each a petrol engine with four vertical cylinders driving through a flexible coupling a continuous-current compound-wound generator running at 500 volts. The engine and the generator are supported on one bedplate. This group, placed transversely in the driver's cabin, supplies electrical energy to the two electric motors which drive the two axles of the car. These cars have only one driver's cabin and are turned on the turn-tables used for the steam locomotives.

A controller is fitted in the driver's cabin with one handle for operating the car in either direction and connected for series-parallel working, the speed of the car being controlled in that way. This controller is fitted with four notches for forward running, and only one for reverse. The driver's cabin also contains a switchboard on which is mounted an automatic circuit breaker, an ammeter, a voltmeter, a valve for the air brake, and a hand brake. The air required for the brake is supplied by an air compressor worked electrically and provided with an automatic pressure regulator. The engine is started by means of a removable handle. An arrangement for omitting the compression facilitates the starting of the engine.

The petrol tank and the water tank are placed in the cabin, and the radiator and the silencer are fixed on the roof of the car. The engine has mechanically-operated valves, a pump for circulating the jacket water, a high-tension magneto for ignition, and a constant-level carburetter, the amount of each charge being regulated by the throttle valve. This valve can be worked by hand, or automatically by an electro-magnet inserted in the armature circuit of the generator. When the current is interrupted by means of the controller, the engine runs at the reduced speed of 300 revs. per minute.

When the petrol engine is running at the reduced speed and the controller is brought into operation, the current supplied by the generator has the effect of opening gradually the regulating valve, and consequently of increasing the speed and the power of the engine. When the speed of the engine is sufficiently high, the car starts and its speed can be regulated by the controller.

The two 4-pole motors are of the series type. The field coils of each motor are connected two in series, and each pair can be connected in series or parallel. At the first forward notch of the controller the two motors and the two fields of each motor are connected in series. At the second notch, the two motors are connected in series and the two fields of each motor are connected in parallel. At the third notch, the two motors are connected in parallel and the two fields of each motor are in series. At the fourth notch, the two motors and the two fields of each motor are connected in parallel. On the reversing notch the connections are the same as for the first forward notch, but the current is reversed in the armatures of the motors.

In order to pass from one notch to another, whether for increasing or decreasing the speed of the car, the driver first operates the control valve so as to reduce the speed of the petrol engine, then places the controller in the position

required for the desired speed, and finally brings back the control valve to its first position corresponding with normal speed. This method of working is to prevent the current being broken at the controller. The 40 h.p. petrol engines have four cylinders each of 120 mm. diam. and 130 mm stroke, and supply the above horse power at 1,000 revs. per minute. The 70 h.p. engines also develop this power at 1,000 revs. per minute, and have four cylinders of 150 mm. diam. and 180 mm. stroke.

The cars are heated by the water which circulates in the cylinder jackets and are lighted by means of acetylene. The 40 h.p. cars provide seating accommodation for 42 passengers, weigh 13 tons, and contain a driver's cabin, a third-class compartment, a platform giving access to the latter, a lavatory, a guard's compartment, and a luggage compartment. The 70 h.p. cars provide seating accommodation for 39 passengers, weigh 16·5 tons, and contain a driver's cabin, a luggage compartment, a second-class compartment, a platform giving access to these, a lavatory, and a first-class compartment. Each of these motor-cars is capable of hauling two trailers with seating accommodation for 96 passengers, and of a total weight of 12·6 tons.

Motor-vehicles of the Société Westinghouse du Havre.

The majority of the motor-vehicles used in Europe have been equipped by the Société Westinghouse du Havre. The motor-vehicles on the Westinghouse system have either one or two driver's cabins, according as to whether they have to run in one or both directions, and are of two types. The first has a 60 h.p. petrol engine with four cylinders, and the other has a 90 h.p. engine with six cylinders. All these cars have been constructed on the same principle. The engine has vertical cylinders of 140 mm. diam. and 160 mm. stroke, and is connected through a flexible coupling to a continuous-current generator with shunt excitation. The pressure of the generator can be varied between 300 and 550 volts by altering its excitation and the speed of the petrol engine. The generator supplies current to the two electric motors driving the axles of the car.

The electrical plant is always placed crosswise in the driver's cabin. There is only one exception to this arrangement: the motor-trains used on the railway system of the Compagnie de l'Ooster Stoomtram (Holland), which does not carry passengers, the electrical plant being placed parallel to the axles in the centre of the car in a special compartment situated between the two luggage compartments. The engine and the generator are placed on a frame of rolled sections. In order to minimise the vibrations caused by the explosions of the engine a block of wood and an elastic plate are placed between the bedplate of the electric generator and the frame of the car. Each driver's cabin contains a special controller with two handles for connecting the motors in series or parallel, adjusting the excitation of the generator, varying the speed of the petrol engine, and of the car in either direction; also measuring instruments, an ammeter, a voltmeter, a circuit-breaker, &c., and apparatus for controlling the hand brake and the air brake; the air brake is generally fed by an electrically-operated compressor having an automatic pressure regulator.

The petrol tank and the water tank are fixed in the cabin containing the engine. The petrol tank has a double casing and is filled from the outside. The radiator and the silencer are placed on the roof of the car. The engine, which is fitted with mechanically-operated valves, water cooling, and high-tension magneto ignition, has an arrangement for omitting the compression, so facilitating starting up by means of a handle. A centrifugal governor, acting on the air admitted to the carburetter, limits the speed of the engine to about 1,000 revs. per minute.

The driver starts the car and regulates the speed by means of the controller. The operation of the controller handle, as in the case of a tramcar, connects the motors in series or parallel, and also varies the excitation of the generator. To vary the amount of air admitted to the carburetter, and thus the speed of the engine, the driver turns the top portion of the controller handle, which, by means of a connecting wire, acts on the governor of the engine. This control is therefore independent of the field circuit of the generator and the connections of the motors. If the stud in the handle is released, the engine slows down, the dynamo ceases to generate current, and the car stops. This contrivance operates therefore in the case of any failure on the part of the driver.

The two motors are first coupled in series and all resistance cut out of the generator field, the pressure supplied by the generator being determined by the speed of the set. The two motors are then connected in parallel, the generating set running at its maximum speed, and the excitation, which had previously been reduced, being gradually increased.

On a certain number of the cars a combined voltmeter-ammeter has been installed, which enables the driver, by observing the point where the two needles cross, to keep the power supplied by the set as constant as possible. The carriage is heated by the circulating water from the cylinder jackets of the engine. The lighting is generally by acetylene, this gas being dissolved under pressure in acetone contained in a bottle. These Westinghouse cars, the dimensions of which vary according to the railway system on which they are used, are able to haul one or two trailers.

Motor-vehicles of the Bergmann Elektricitäts-Unternehmungen Aktien-Gesellschaft.

For some years past the Prussian State Railways have been endeavouring to develop the use of motor-vehicles. After having successively adopted steam motor-cars and accumulator cars, the Prussian State Railway management in 1907 started to experiment with petrol-electric motor-vehicles; the results of these tests were sufficiently satisfactory to induce these authorities to go in for some petrol-electric cars, the construction of which was entrusted to the Allgemeine Elektricitäts Gesellschaft and the Bergmann Elektricitäts-Unternehmungen Aktien-Gesellschaft. The cars constructed by the two companies on the lines apportioned to them have many points in common.

Each of the cars equipped by Messrs. Bergmann comprises an electric generating set, spring-supported, which rests directly on the two axles of one of the two bogies of the car, the other bogie carrying the two electric motors to which current is supplied by the generator. This arrangement and the spring suspension of the generating set on a bogie facilitate the rapid replacing of the set, and avoid the transmission of the vibrations due to the engine to the body of the car. Moreover, the body of the car is entirely distinct from the generating plant, the engine being covered with a removable hood. This arrangement, based on that usually adopted on automobiles, has the advantage of avoiding all heat and smell in the interior of the car, and also reduces the danger of fire to a minimum.

The benzol engine has six cylinders, each of 170 mm. diam. and 180 mm. stroke, the two groups of three cylinders being arranged in the form of a V, the angle between each set of three cylinders being 60°. The engine develops about 100 h.p. and runs at 700 revs. per minute. The centrifugal governor controls the admission of the gas, and is connected to the controller handle, so that the speed of the engine is reduced automatically to one-third when the engine runs without a load. The silencer is placed vertically in front of the forward partition of the body of the car.

The electric lighting is effected by a battery of accumulators, which is also required for other purposes. Forced lubrication is used; and the water for cooling the engine is circulated by a rotary pump. The radiator is placed on the roof of the carriage, and an electrically-driven fan blows air on the radiator in such a way as to cool the water whatever the speed of the car may be. The car is heated by the circulating water.

The engine is started by means of compressed air, three of the cylinders working as 2-cycle compressed-air motors, whilst the remaining three cylinders take in carburetted air. Thus, during starting, the engine operates in two ways, viz., with compressed air and with liquid fuel. The compressed air is obtained from the reservoir for the air brake, the air compressor being driven by a benzol engine. The engine weighs 2,500 kg. The liquid fuel is stored in a reservoir, being covered with an inert gas under pressure, either nitrogen or carbonic acid being used; the latter are stored in a gas cylinder. The reservoir, with the idea of reducing leakage, has only one opening on the top, and is placed as low as possible. The continuous-current generator, the pressure of which is varied by altering its excitation, is direct-coupled to the engine, and is fitted with commutating poles and a com-

pensating winding. It can develop continuously 66 kw. at a pressure of 300 volts and a speed of 700 revs. per minute. As the speed of the car is only controlled by varying the excitation of the generator, it is necessary to use accumulators to maintain a steady pressure for the electric lighting of the car, the electric alarm bell, the field windings of the motors, and for exciting the main automatic switch. By means of the arrangement described below, this generator with its variable pressure can supply current to the auxiliary circuit for charging the battery.

The principle of this arrangement is as follows: The generator has a shunt field winding of the ordinary type connected between the two terminals of the machine, but with this difference, that a portion of this winding is permanently connected in parallel with the battery of accumulators; and in series with the remaining portion of the winding is a rheostat. On the first notch of the controller, the portion in parallel with the battery is alone in circuit, and is fed by this battery. This portion of the winding is designed so that when the generating set has gradually reached its normal speed of 700 revs. per minute the excitation is sufficient to start the car. On the second and following notches the two portions of the shunt winding and the rheostat are inserted in series between the two terminals of the generator, one part of the winding, however, remaining in parallel with the battery. The resulting excitation is produced, on the one hand, by the circulating current due to the pressure of the generator, which feeds both portions of the shunt winding, and on the other hand by the supplementary current supplied by the battery in that portion of the winding which is in parallel with the battery. On cutting out the resistance gradually, the pressure of the generator will increase, whilst the current supplied by the battery will diminish, and finally reverse, the battery then being charged by the generator. Each of the two electric motors, which are of the series type and are fitted with commutating poles, develops 85 h.p. for one hour.

The car has at each extremity a driver's cabin containing a controller, the apparatus for working the hand brake, and the compressed-air brake, as well as the safety apparatus. The controller has two handles, one for changing the direction of motion of the car, and the other for regulating the speed. The latter handle is fitted with a push button, so that should the driver remove his hand from the controlling handle when the latter is on one of the forward notches, the whole of the current is cut off and the compressed-air brake is immediately brought into action.

The following are the principal dimensions of the car:—

	Metres.
Length over buffers	20·75
Distance between the axles of the two bogies	13·8
Wheelbase of each bogie carrying the generating plant	3·8
Wheelbase of the bogie carrying the electric motors	2·5
Length of the body of the car	16·5

The car has two compartments, that near the electric generating set is a fourth-class compartment with seating accommodation for 22 passengers and standing room for 28; the other is a third-class compartment with seating accommodation for 50 passengers. This car with its accommodation for 100 passengers weighs 47 tons, and reaches on a level a speed of 70 km. per hour. The benzol engine was constructed by the Gasmotoren-Fabrique Deutz, and the electric equipment was supplied by the Bergmann Company.

MOTOR-VEHICLES OF THE ALLGEMEINE ELEKTRICITÄTS GESELLSCHAFT.

The motor-vehicles supplied by the A.E.G. Company for the Prussian State Railways are arranged to a considerable extent on the same plan as those of the Bergmann Company. The electric generating set is carried by one bogie, and the two electric motors by the other. The body of the car is self-contained, and the benzol engine is covered with a removable hood. The car has two driver's cabins. The benzol engine has four vertical cylinders of 196 mm. diam. and 260 mm. stroke, mechanically-operated valves, spray carburetter, high-tension magneto ignition, and water cooling. It is provided with a centrifugal governor, which limits the speed to 700 revs. per minute. At that speed the engine develops 120 h.p. A special device operated by the controller automatically reduces the speed to 250 revs. per minute when the engine runs without load.

The engine is started by compressed air, and drives the generator through an elastic coupling. The continuous-current generator, which has commutating poles, and is arranged for shunt and independent excitation, gives a pressure of 300 volts and a normal power of 66 kw. The compound-wound exciter gives 70 volts and a power of 2·5 kw., and is fixed on the shaft of the main generator. Each electric motor is rated at 82 h.p. for one hour. The speed of the car is controlled by varying the independent excitation of the generator. The electric lighting of the car is supplied from the exciter and the battery, which are connected in parallel when the speed of the electric generator is 700 revs. per minute. When the speed is below this (that is, when the engine runs unloaded), the exciter is automatically cut out of circuit by means of a circuit breaker; the lighting is then obtained from the battery.

This car, the body of which is 16·495 metres long, comprises a third-class compartment and a fourth-class compartment, and provides accommodation for 95 passengers. In working order this car weighs 55 tons, and has a speed on the level of 65 km. per hour. This car was placed in service in October, 1911. The benzol engine was constructed by the Neuen Automobil Gesellschaft, and the electric equipment was supplied by the A.E.G.

The same company has built, for branch lines, another type of petrol-electric car of 55 h.p., which was recently placed in service on the East German railway system at Königsberg, East Prussia. The electric generating group is situated in one of the two driver's cabins, but is supported on springs from the frame of the bogie beneath. By this arrangement the vibrations of the engine are not transmitted to the body of the car. The two electric motors are placed on the other bogie. The benzol engine has four vertical cylinders and is water cooled. It has forced lubrication, high-tension magneto ignition, and a centrifugal governor, and develops from 55 h.p. to 58 h.p. The radiator is placed on the roof, and the water and benzol reservoirs are placed in the driver's cabin. The benzol engine drives the generator through a flexible coupling. The generator is of the continuous-current type, and has commutating poles and separate excitation. The exciter is belt driven from the engine. The control of the car is effected by varying the excitation of the generator. This car has seating accommodation for 12 passengers in the second-class, and 15 in the third-class compartment, and it attains a speed on the level when two trailers are attached of at least 30 km. per hour.

MOTOR-VEHICLES OF THE GENERAL ELECTRIC COMPANY.

The motor-vehicles of this company, which are used to some extent in the United States of America, all have the same type of petrol-electric equipment and the same arrangement of their component parts. The General Electric Company's motor-vehicles have only one driver's cabin, the front of which is torpedo-shaped in order to reduce the resistance of the wind. This cabin contains the main generating set and an auxiliary generating set. The two electric motors are lodged on the front bogie beneath the driver's cabin. The main set, which is placed longitudinally in the car, consists of a gasolene engine driving at one side an electric generator and at the other an air compressor. The auxiliary set, also placed longitudinally but at one side of the car, comprises a petrol engine driving an electric generator and an air compressor.

The main engine has eight cylinders of 203 mm. diam. and 254 mm. stroke arranged in the form of a V. The engine is cooled and has mechanically-operated valves and two low-tension magnetos for ignition, with magnetic break. Forced lubrication is used, and the engine is provided with a valve for regulating the speed. The normal speed of this engine is 550 revs. per minute. The main electric generator, mounted on the engine shaft, has eight poles as well as commutating poles, and supplies continuous current at 600 volts, being capable of supplying a power of 100 kw. Its carcase is bolted to the bedplate of the engine, the end of the shaft being supported in a bearing. The main air compressor, directly fixed to the engine shaft, has a cylinder of 120 mm. diam. and 101·6 mm. stroke. This compressor is fitted with an automatic pressure regulator. The starting of the main engine is effected by means of compressed air contained in reservoirs placed on the car, and which are supplied by the compressor of the main set or of the auxiliary set.

As the voltage of the generator varies from 200 to 800 volts, according to the power required for traction, it is

necessary, to ensure the satisfactory electric lighting of the car and to supply the initial charge of air for starting the main engine, to use an auxiliary set. The auxiliary engine has three vertical cylinders, the one in the centre being used as an air compressor. The other cylinders have a diameter of 120 mm. and a stroke of 152 mm. The compressor cylinder has a diameter of 133 mm. and a stroke of 152 mm. This cylinder can supply compressed air at a pressure of 6 kg. per square centimetre. A centrifugal governor maintains the speed of the engine—600 revs. per minute—constant. This engine is started by hand. The cooling system and the ignition are the same as in the case of the main engine.

The auxiliary generator, which gives a pressure of 125 volts and has a capacity of 1·5 kw., is direct-coupled to the engine shaft. The two electric motors, which are fitted with commutating poles and are of the G.E.-205 type, are designed for a pressure of 600 volts and can each develop 100 h.p. for one hour. The starting of the car and the regulation of the speed are carried out by means of the controller, which connects the motors in series and parallel and varies the excitation of the main generator. The controller has three handles—the first one for changing the speed of the car, the second for connecting the motors in series, &c., and adjusting the excitation of the generator, and the third one for starting the engine by compressed air and regulating the admission of the gas. The last-mentioned handle is so arranged that when pressure is brought to bear on a lever fixed to the handle, compressed air is admitted to the engine through a valve placed beneath the controller, whilst the gas can be admitted at the same time. It is arranged so that the gas is only admitted at the correct instant to ensure the working of the engine. The engine once started, the lever can be released, stopping completely the admission of compressed air. It is not possible to admit the compressed air again to the engine without bringing the handle to its initial position, corresponding with the shutting off of the gas.

The radiator is placed on the roof of the car. The petrol engine is placed on the car itself, and a pump worked by the engine sucks in the petrol. A hand pump has to be used instead of this pump when the engine is not running. A hot-water stove heated with coal is used to warm the car. The stove can be connected with the circulating water for cooling the engine in order to prevent the water freezing and cracking the cylinders when the car is put in the shed for the night. The cars are constructed entirely of metal, and, according to the type to which they belong, have seating accommodation for 60 to 100 passengers, and weigh from 40 to 50 tons, of which 6 tons is accounted for by the bogies and 15 tons by the petrol-electric equipment. They are capable of developing a draw-bar pull of about 5,500 kg., and a speed on the level of about 90 km. per hour.

Motor-vehicles of the British Thomson-Houston Company.

The Great Western Railway Company of England is at present experimenting with a motor-vehicle having only two axles, and the electric equipment has been supplied by the British Thomson-Houston Company. The car consists of two driver's cabins, one at each end, and a compartment for passengers. The petrol engine of 40 h.p. drives a dynamo which supplies current to two electric motors, each of which transmits power to one axle. The generator set is placed in one of the driver's cabins. This car weighs 14 tons, and has seating accommodation for 44 passengers.

(*To be continued.*)

The Junior Institution of Engineers.— The programme of arrangements for June is as follows: June 7th, at 4-30 p.m., visit by the Midland Section to the Printing Works of the Birmingham "Daily Post" and "Daily Mail," Birmingham. June 14th, at 3 p.m., visit the "Daily Mail" Printing Offices, Carmelite House, Tallis Street, E.C. June 26th, 2 p.m., visit the Biscuit Works of Messrs. Peek, Frean, & Co., Ltd., Keeton's Road, S.E. June 30th, 8 p.m., at the Institution of Electrical Engineers, Victoria Embankment, Gustave Canet Lecture on "The Working Fluid of Internal-combustion Engines," by Dr. Dugald Clerk, F.R.S., M.Inst.C.E. Tickets may be had on application to the Secretary, 39, Victoria Street, S.W. At 8 p.m., at the Great Western Hotel, Birmingham, Dr. Dugald Clerk's lecture will be delivered before the Midland Section by Mr. A. A. Remington, M.I.Mech.E. Tickets may be had on application to 60, Anderton Park Road, Moseley, Birmingham.

FENCING OF MACHINERY IN TEXTILE MILLS.

Two white papers have been issued by the Home Office giving the results of conferences between representatives of employers and workpeople regarding the fencing of machinery and other precautions for the prevention of accidents in worsted and cotton mills.

The Chief Inspector of Factories, Mr. Arthur Whitelegge, in a prefatory note, states that following the conferences on the prevention of accidents in cotton spinning and woollen and worsted mills, conferences were promoted during November and December in respect of cotton weaving factories. The report relating to cotton mills is the joint production of Mr. Gerald Bellhouse and Mr. John Jackson, two Superintending Inspectors of Factories. The conferences were held at Blackburn and Manchester, and the matters considered were (1) Fencing of machinery and other safeguards; (2) spacing of looms; (3) cleaning machinery; (4) the lifting of heavy weights; and (5) the lighting of passages and stairways. The discussions were very amicable, and a full measure of agreement was arrived at.

With regard to the cleaning of machinery, the Inspectors made the following observations: "Restrictions as to cleaning under looms while in motion were agreed to only as regards women, young persons, and children. Employers contended that a rule of this kind should not be applied to male adults, who by their experience and training are better able to look after themselves, and are therefore less liable to accidents. The operatives, on the other hand, held strongly to the view that no distinction should be made between males and females, but they accepted the rule as it stands on the grounds that it is beneficial so far as it goes." As a basis, Mr. Bellhouse drew a code of rules for the fencing of machinery and the safeguarding of workers, and with slight alterations they were finally agreed to. Among the rules is one that any woman or girl working about machinery shall have her hair put up or otherwise confined in a net.

The lifting of heavy weights is dealt with as follows: (1) Women, young persons, and children shall not be employed to lift, carry, or move anything so heavy as to be likely to cause injury to them; (2) women, young persons, and children shall not assist the overlooker in lifting beams into the looms.

From the report dealing with worsted mills, which is by Mr. James H. Hine, Superintending Inspector of Factories for the North-eastern Division, it appears that very similar agreements were arrived at, and at the last meeting it was proposed that the conference should meet again in March, 1914.

INDUSTRIAL AND TRADE NOTES.

The Strike in the Midlands.—The strike of tubemakers in the Midlands has spread to other trades until at the present time close on 30,000 men are affected. Several large firms in the district have posted lock-out notices to terminate all employment as from Saturday next, so that unless some settlement is shortly arrived at the number will be considerably increased.

Midland Ironworkers' Wages Raised.—On Saturday last the Midland Iron and Steel Wages Board declared the average net selling price for March and April to have been £8. 8s. 10d., as compared with £8. 4s. 7d. in January and February. The production was 32,464 tons, against 39,425 tons two months back. Ironworkers' wages are advanced 2½ per cent., making puddlers' wages 11s. 3d. per ton.

Airship Construction at Barrow.—Messrs. Vickers, Ltd., who have been commissioned by the Admiralty to build five new airships, have acquired a considerable area of land on Walney Island, Barrow, where they are arranging to put down works for the building of all classes of airships, aeroplanes, hydroplanes, &c. The new works will, when finished, furnish employment for about 1,000 men.

Clyde Shipbuilding.—There was launched from shipbuilding yards on the Clyde during the past month 37 vessels of 56,836 tons. The total for the five months of this year is 105 vessels of 293,997 tons Although these figures are well ahead of those for the best previous year and work on the stocks is plentiful, it cannot be said that prospects are satisfactory. Builders are heavily handicapped by the lack of men and the restrictions which several trade unions have laid on their members with regard to overtime, while the possibility of a great strike in the near future is not improbable.

Suggested Ship Canal for Leeds.—The question of a ship canal for Leeds was on the 27th ult. brought before the Lord Mayor of that city by an influential deputation. It was held that Leeds was not progressing satisfactorily, and that a new waterway was absolutely necessary for the heavy trades. The Lord Mayor, in reply, said the moment had not yet arrived when he should intervene. A good deal of spade work had got to be done, and the matter ought to be ventilated a little more. He declined to call a public meeting, but suggested that the Chamber of Commerce should discuss the question.

North of England Ironworkers' Wages Advanced.—The ascertainment of the accountants to the Board of Conciliation for the manufactured iron and steel trade of the North of England shows that the average net selling price in March and April of the four classes of iron with a total production of 13,009 tons is £7. 10s. 2·82d. per ton, as compared with an output in January-February of 13,503 tons, with the net average selling price £7. 7s. 3·89d. per ton. Wages will be advanced 3d. per ton on puddling, and 2½ per cent. on all other forge and mill wages, the advance taking effect from June 2nd.

Wages in the Shipbuilding Trade.—Representatives of the Shipbuilding Employers' Federation and of the Boilermakers' Society met in conference at Carlisle on the 27th ult. to consider the situation with regard to wages. The meeting terminated without any definite result. It is probable another conference will shortly be held in Edinburgh, when the result will be known of the ballot now being taken on the subject of giving the men's executive power to order a cessation of work on the question of a general advance of 5 per cent. in wages which is being put forward by other shipyard trades working under the national agreements.

Development of Wireless Telegraphy.—The Marconi Wireless Telegraph Company of Carada announce that they have concluded a contract with the Canadian Government for the supply and erection of wireless telegraph stations at La Pas (Manitoba) and Port Nelson (on Hudson Bay), which will thus for the first time be brought into direct telegraphic communication with the rest of the world. The Port Nelson station will also be of the greatest utility in the development of the Hudson Bay Route between the Canadian North West and Europe, and particularly as concerns the navigation of the several vessels already chartered for the service, and which are fitted with wireless by the Marconi Company.

Proposed Development of Chilian Copper Mines.—H.M. Legation at Santiago reports that a United States syndicate has recently purchased the Chuquicamata group of copper mines in Chile for £180,000. Exhaustive tests have been made of the deposits, which are now estimated to contain 100,000,000 tons of low-grade ore assaying from 1½ to 1¾ per cent of copper. The syndicate proposes to spend £1,500,000 on the development of the property and the erection of an up-to-date plant capable of dealing with 10,000 tons of ore daily, producing about 62,500 tons of pure copper per annum. As the production of copper in Chile only amounted to 37,902 tons in 1912, it will be seen that this scheme, if successful, will nearly treble the present output of the country.

Railway Traffic in 1912.—The Commercial Department of the Board of Trade has just issued a preliminary return relating to the railways of the United Kingdom for 1912 with comparisons. There is little variation shown in the length of line open for traffic, the total for last year being 23,442 miles, as compared with 23,417 miles in 1911. The authorised capital was £1,410,723,000. The number of passengers conveyed during 1912 was 1,294,486,000, as compared with 1,326,316,990 in the previous year. In addition the holders of season or periodical tickets numbered 786,000, as against 779,173. A total of 401,301,000 tons of mineral was conveyed and 118,720,000 tons of general merchandise, making together 520,021,000 tons, as against a gross total of 523,577,178 in 1911.

The Proposed Forth and Clyde Canal.—The Glasgow Corporation Special Committee on the proposed Forth and Clyde Canal recommend that the Corporation again memorialise the Government that, "from its strategic value, and its value to the commerce of the country, it is desirable that a canal suitable for the passage of battleships and all vessels of the largest size should be constructed between the Forth and Clyde, viâ the Direct Route," and that copies of the memorial be sent to the members of Parliament; also that it be remitted to the Town Clerk to ascertain whether the owners on the line of the proposed direct route are prepared to grant land for the construction of the canal free, in view of the development of their land which would follow by the construction of the canal.

Shipwrights' Association's Report.—The quarterly report of the Ship-constructors' and Shipwrights' Association, which has just been issued to the branches, states that the shipbuilding and ship repairing industry during the quarter has been one of continued prosperity and full employment for the members, and so far the year had fulfilled the predictions which were made in the latter end of last year as to the continued prosperity of the industry. The income for the quarter was £13,647, whilst the expenditure had been £12,642, leaving a net gain on the quarter of £1,005, which, added to the balance in hand at the end of December, brought the total worth of the Association up to the end of March to £127,462. During the quarter 503 new members had been admitted, and the membership at the end of the quarter was 26,546, which figures showed a slight increase on the previous quarter.

Iron Ore Deposits in Chile.—H.M. Legation at Santiago writes that, in view of the increasing demand and reputed shortage of the supply of iron ore throughout the world, it may be of interest to point out that the deposits in Chile, chiefly in the province of Coquimbo, have now been proved to amount to several hundreds of millions of tons of a high grade ore, in some cases containing 64 to 71 per cent of iron. The high rate of freight, however, checks enterprise, since the ore cannot be shipped to Europe at a profit. For this reason a French company working the deposits at Tofo was compelled to give up shipping ore to Glasgow. It is believed that the present high rates are merely temporary, and that once the large number of smaller steamers at present building are finished and the Panama Canal is opened, freight rates will fall all over the world, especially to and from the West Coast of South America.

Roumanian Petroleum Industry.—According to a report by H.M. Consul at Galatz, Roumania as a producer of petroleum occupies the fourth place among the countries of the world, coming after the United States of America, Russia, and the Netherlands Colonies. The capital invested in the industry in Roumania is estimated to be over £11,000,000, divided among 59 companies; of these, 28 companies realised a net profit of £1,683,000 during 1911; 27 companies show a loss on working of £608,000; while the remaining four companies show neither profit nor loss. The value of the yield of 1,625,000 tons for the last statistical year, 1911-12, is estimated at £2,000,000, and is distributed among the various districts as follows: Prahova, 1,440,765 tons; Dambovitza, 88,971 tons; Buzeu, 68,981 tons; Bacau, 26,402 tons. In 1911, the last year for which statistics are available, there were 65 refineries in the country, which between them dealt with over 90 per cent. of the total output of crude petroleum. Complaints have been made regarding transport facilities, and it is stated that a number of productive wells were compelled to shut down during 1912 owing to the shortage of locomotives.

Proposed Italian Hydro-Electric and Irrigation Works.—A Commission has, we understand, been nominated to examine a Bill introduced by the Italian Minister of Public Works for the development of the water forces in Calabria and Sardinia. These works are to be entrusted to private enterprise, and concessions will be given for a period of 30 years, which may be prolonged for a further 30 years. It is proposed to construct an enormous basin along the bed of the Tirso river in Sardinia for the storage of water for irrigation purposes and the supply of motive power. By means of a dam 53·50 metres in height, it is calculated that a lake holding 330 million cubic metres of water and measuring 60 kiloms. in circumference would be formed. Whilst in the summer this river is of scarcely any value owing to its paucity of water, in the rainy season it overflows and does untold damage to the Oristano plains and the surrounding districts. It is estimated that a force of roughly 10,000 h.p. would be obtained, and by means of three principal canals, totalling in all about 30 kiloms. in length, would irrigate an area of some 20,000 hectares, which cannot at present be profitably employed for agricultural purposes owing to the scarcity of water in summer. The cost of the hydraulic works in this case will amount to one million sterling, without taking into consideration the power required for subsidiary canals, &c. A Commission of Government engineers which visited Calabria prepared various plans for opening up the Sila district. The chief source of water will be derived from the Neto and its tributaries, the Arvo and Ampollino. The present project is to bar the course of the Arvo by a dam 40 metres high; the Ampollino by a dam 29 metres high; and the Neto by one 62 metres high. These would form reservoirs holding respectively 157, 61, and 17 million cubic metres of water. It is calculated that these works will produce about 170,000 h.p., and will cost about £2,500,000 sterling, and that the power developed will be sufficient to supply the needs of Puglia, Calabria, and Basilicata for traction and lighting, &c.

The Metric Carat.—The Standards Department of the Board of Trade has decided to make the metric carat of 200 milligrams, and its necessary multiples and sub-multiples, standard weights in the United Kingdom. The order giving effect to this decision will, it is understood, be issued before the end of the year.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Toothed gearing. Humphris Patent Gear and Engineering Company, and Smith. 3425.
Wire drawing and apparatus therefor. Watson, and W. D. Houghton & Co. 3804.
Spur gearing. Alquist. 8371.
Water heaters. Stott & Schofield. 10955.
Riveting and caulking machines. Cross. 10982.
Speed changing mechanism for wire drawing machines. Oakden 11001.
Internal combustion engines. Roots. 11030.
Metallic packing for piston rods. Robinson & Beldam. 11044.
Rotary cylinder internal combustion engines. Harris & Barnard. 11100.
Aeroplanes. Huntington. 11154.
Process of and apparatus for refrigerating by ammonia expansion and absorption. Withers. 11347.
Carburetters for internal-combustion engines. Werner and Pfleiderer Oesterreichische Industrie Werke Kommandit Ges. 11368.
Starting internal-combustion engines. Scott. 11388.
Gearing for driving and reversing metal planing machines. Joshua Buckton & Co., and James. 11413.
Extraction of tin and other metals from tin ores and slags. Gibbs. 11643.
Cocks and valves. Andriveau. 11700.
Rotary cylinder explosion engines. Rolando, Rolando, & Gintz. 11763.
Internal-combustion engines. Boyd. 12045.
Railway signalling apparatus. Stitt. 12649.
Steam turbines. Cross. 13000.
Screwing machines. Hampton & Beebee, Ltd., and Hampton. 16158.
Lathe dogs. Michaud. 17017.
Telpherage. Robert Dempster & Sons, Ltd., and Toogood. 17550.
Wave motors. Stribling. 17595.
Variable speed friction gearing for use on motor vehicles. Mead. 17808.
Self-closing isolating valve for steam pipes. Halse. 18735.
Inside gauges and inside micrometer gauges. Williams. 19011.
Driving chains. Renold, and Hans Renold, Ltd. 20318.
Turbine water-wheel. Edming. 22205.
Ball or roller bearings. A Ransome & Co., Marles, and Jones. 23264.
Controlling mechanism for riveting machines. Jay. 23933.
Mechanical stokers for locomotives. Kometter. 25676.
Method of uniting sheets of brass, aluminium, and other metals of high conductivity for heat. Prostler & Ges. fur Elektrotechnische Industrie. 25987.
Air-cooled multi-cylinder internal combustion engines having rotary valves. Lentz. 26285.
Device for governing a steam turbine. Vereinigte Dampfturbinen Ges. 26885.
Differential governors for the control of reciprocating steam engines. Das 27149
Centrifugal apparatus for purifying, cooling, and washing gases Theisen. 27417.
Process and apparatus for testing metal sheets and plates. Erichsen. 28571.
Portable rotary hammer. Leonardi. 28651.
Aeroplanes. Hyde & Gaul. 29053
Means for lubricating internal combustion engines. Best & Lloyd, Ltd., and Carpmael. 29509.
Apparatus for washing, grading, and concentrating ores and minerals. Michel. 29617.

1913.

Device for utilising the waste heat of the Cowper apparatus in blast furnaces. Pregardien. 1169.
Steam or gas turbines. Weishäupl. 1614.
Forging axles and dies employed therein. John Baker & Co. (Rotherham), and Baker. 2984.
Flying machines. Hirth. 5246.
Steam turbines. Aktiebolaget Ljungstroms Angturbine. 6077.
Oblique or stepped grate furnaces. Werger. 6941.
Devices for steering aeroplanes. Huntington. 10263.

ELECTRICAL, 1912.

Electric resistance bodies. Cooper. 11380.
Closing electric circuits. Pillinger & Sunderland. 11486.
Electric switches. Hunter & Shand. 11586.
Vapour electric apparatus. Darmois & Leblanc. 11870.
Telephone systems. Mellinger. 11964.
Mercury vapour lamps. Triquet. 12270.
Bi polar form wound rotor windings for dynamos. Schneider. 12766.
Automatic electric thermal control. Price. 15178
Electric heater. Purle. 15429.
Production of magnetic or electric fields. Plohl. 15774.
Means for obtaining a protective layer on iron and steel electrodes. Gibbs. 15852.
Systems of cable working for electric telegraphs. Gott. 22364
Selective signalling apparatus for telephone and telegraph instruments. Roose & Finlay. 28486.
Electric relays. Nicholson. 30059.

1913.

Electric motor meters. H. Aron Elektricitatszahlerfabrik Ges. 792
Distributor for electric ignition in internal combustion engines. Robert Bosch. 5532.

METAL QUOTATIONS.

TUESDAY, JUNE 3RD.

Aluminium ingot	95/- per cwt.
„ wire, according to sizes, &c. ......from	112/- „
„ sheets „ „ ...... „	126/- „
Antimony ......£31/-/- to	£33/-/- per ton.
Brass, rolled	$8\frac{1}{2}$d. per lb.
„ tubes (brazed)	$10\frac{5}{8}$d. „
„ „ (solid drawn)	$9\frac{1}{2}$d. „
„ „ wire	$8\frac{3}{8}$d. „
Copper, Standard	£66/10/- per ton.
Iron, Cleveland	58/9 „
„ Scotch	64/9 „
Lead, English	£20/5/- „
„ Foreign (soft)	£19/12/6 „
Mica (in original cases), small	6d. to 3/- per lb.
„ „ „ medium	3/6 to 6/- „
„ „ „ large	7/6 to 11/- „
Quicksilver	£7/10/- per bottle.
Silver	$27\frac{5}{8}$d. per oz.
Spelter	£22/17/6 per ton.
Tin, block	£210/-/- „
Tin plates	$14/1\frac{1}{2}$ „
Zinc sheets (Silesian)	£27/10/- „
„ (Stettin; Vieille Montagne)	£28/12/6 „

Refined Spelter for Manganese-bronze.—In making ordinary brass or composition castings, the cheapest grades of spelter are satisfactory. The lead in it does not need to be considered as it is rare indeed that this metal is not introduced in the mixture; and those in which no lead is used like gun-metal (88-10-2) the amount of spelter employed is so small that the lead in it is reduced to an insignificant quantity. For example, in the 88-10-2 gun-metal mixture, 2 per cent. of spelter is used, and if it contains 1 per cent. of lead, then the finished gun-metal would contain only 0·02 per cent. of lead. An amount so small that it need not be considered. In the case of the so-called manganese-bronze, however, the case is different. Such mixtures contain some 40 per cent. of spelter, and if there is considerable lead in it, then nearly half of it enters the manganese-bronze. It will be appreciated, therefore, that the question of lead in spelter to be used for manganese-bronze is far more important than it is in the ordinary brasses or composition. Lead always affects the physical properties of the brasses and bronzes containing it, and in the manganese-bronzes it will be found to lower the tensile strength, elongation, and reduction in area. It particularly reduces the elongation and the reduction of area. For this reason, if the highest physical qualities are desired, a spelter free from lead or as free as possible should be used in making up the manganese-bronze mixture. It is impossible, of course, to obtain any spelter absolutely free from lead, but the best grades of refined metal will not contain over 0·05 per cent. of lead and it is this grade that should be used in making manganese-bronze. Common grades of spelter will run 1 per cent. in lead and often over this amount. Therefore, if such spelter is used in making manganese-bronze, nearly half a per cent. of lead will be introduced in it. Such a quantity cannot have but a deleterious effect on the bronze and will reduce its physical properties to a considerable extent, so much so, in fact, that it will be impossible to meet some specifications.—"The Brass World."

The Mechanical Engineer

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Edited by
WILLIAM H. FOWLER
Wh. Sc., M.Inst.C.E.

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Heat Accumulators for Exhaust Steam.

FEW features in connection with steam-power development during recent years have been more pronounced than the extent to which the heat of exhaust steam previously turned to waste has been utilised. The credit for this is no doubt largely due to the introduction of the turbine, and to the merits, first pointed out by Parsons, which this type of prime mover possesses, as compared with the reciprocating engine, when working with low-pressure steam. His suggestion that the turbine might be substituted for the low-pressure cylinder, or in other cases installed to supplement the high-pressure one, has, as we know, found extensive practical application, especially in marine engineering, where the wing propellers are in several modern liners driven by reciprocating engines exhausting into a low-pressure turbine operating the central shaft. There are many instances, however, in land practice where exhaust steam is available, but where, owing to the intermittent nature of the work the engine has to perform, the non-condensing cylinder cannot be coupled directly to a low-pressure turbine, as, for instance, in the case of rolling-mill engines and colliery winding engines. The latter type illustrates these conditions in probably its most extreme form, since, in order to accelerate the load at the commencement of the wind, steam is admitted throughout the whole stroke for the first few revolutions, after which the cut-off takes place at an increasing rate as the winding proceeds, while towards the end steam is cut off altogether, to allow the engine to gradually come to rest, when a complete stoppage occurs for some seconds to change the load before the cycle is repeated. This intermittent working is one of the difficulties that prevents the easy application of a condenser to this type of engine, since its capacity requires to be designed for the maximum duty to secure the most efficient results, and this is disproportionately large for normal requirements. Some winding engines are, of course, fitted with condensers, but colliery engineers have a strong objection to

their introduction owing to their desire to avoid complication, and to the small economical advantage which, under the circumstances, is attainable. Somewhat similar conditions prevail with steam-rolling engines, and hence large quantities of exhaust steam are in many cases thrown to waste.

The problem of utilising this steam in exhaust turbines for the production of power for electrical or other purposes has led to the introduction of heat accumulators, by which the intermittent source can be converted into a uniformly continuous supply for utilisation with a turbine and condenser. Apparatus of this kind for heating feed water is of course well known, but usually these are of small dimensions, and though Druit Halpin's system of "thermal storage" for use with the peak loads of water-tube boilers approximates in some ways to the needs of turbines, the conditions are simpler, inasmuch as the surplus steam from the boilers during their slack working periods is simply condensed by direct contact with large volumes of water in a supplementary vessel above the boilers, and so constitutes a store of highly-heated feed from which the boilers can draw their supply during periods of heavy working. When steam is drawn from reciprocating engines, however, the possibility of oil troubles must be recognised and guarded against.

Prof. Rateau was among the first to turn his attention to this type of apparatus and to demonstrate its economy, though a number of designs are now available. Essentially, they consist of a vessel partially filled with water, into which the intermittent flow of exhaust steam is conducted, and condensed with a resultant rise in the temperature of the water, and a corresponding increase in the vapour pressure above its surface. This reservoir of heat permits of an approximately steady supply to the turbine during the intervals when no exhaust is flowing to the engine, and which is usually about 30 secs. in rolling-mill work and 60 secs. in colliery winding engines. These are about the longest intervals that have to be dealt with, though accumulators may be designed to bridge longer periods than these. To render the turbine independent of the engines during periods when the reciprocating motor may be stopped for longer periods than usual, it is customary to equip the accumulator with an automatic reducing valve to admit a supply of live steam from the boilers when the pressure in the accumulator falls below some predetermined point. To reap the full advantage of exhaust steam, a good vacuum is, of course, very desirable with turbines, owing to their capacity for dealing with big volumes and low pressures. How substantial is the economy that can be reaped with low-pressure turbines, where circumstances allow of their adoption, is shown by the fact that with a pressure of only about 7lbs. absolute in the accumulator, it is possible with this type of motor to obtain an electrical horsepower at the expenditure of only about 36lbs. to 37lbs. of steam. In the use of heat accumulators, however, it is desirable to emphasize the importance of excluding oil, as a relatively minute quantity on the surface of the water exercises a marked effect on the regenerative process, and for this reason the surface condenser offers advantages. The introduction of an exhaust turbine plant offers in many cases a material source of fuel gain without in any way complicating existing machinery or interfering with the operation of the reciprocating engine in the event of breakdown of the turbine. Against this advantage has of course to be set off capital expenditure and cost of maintenance, but when all these are considered there is a substantial balance to the good, and in collieries and steel works there is room for much wider application of the system than at present prevails.

Corrosion in Refrigerating Systems.

THE influence of air—or rather of the oxygen which forms a component part, and the trace of carbon dioxide (CO_2) always associated with it—on the corrosion of iron and steel is, of course, well known, but the way by which its evil effects in many cases may be mitigated is less appreciated, and for this reason we drew attention a few months ago to some suggestions made by Mr. Speller in the "Engineering News" regarding this practical aspect of the question. Another contribution to the subject by Mr. M. B. Smith in a later issue of our contemporary points out the equal need of arranging for the extrusion of air applies equally to refrigerating systems so largely adopted in hotels and public buildings in the States, where a low temperature is often transmitted by means of brine or ammonia in either gaseous or liquid form. Though our climate does not call for so wide an application of refrigerating systems, they are sufficiently numerous and important to justify a little prominence for the facts he records. His attention appears to have been first drawn to the matter by severe corrosion met with in a large brine-circulating system in a public building in Pittsburg, and localised, almost without exception, to the fittings, valves, and pumps, or their immediate neighbourhood, and always at the upper part. This latter feature, coupled with the discovery that the topmost part of the system was most severely affected, pointed to the presence of air as the cause of the trouble, and this was confirmed by the fact that it was greatly diminished when provision was made for liberating any imprisoned pockets of air by means of pet cocks placed at convenient points, so as to ensure the system being completely filled with brine. The necessity of doing this periodically showed, however, that, apart from the air which was imprisoned from the first owing to the contour of the pipes, &c., an abnormal quantity was carried forward in the solution owing to the return stream of brine being discharged as an open jet about 5ft. above the surface of that in the main tank from which the supply was pumped. A rectification of this error by making the discharge pipe dip below the surface resulted in the reduction of the air content to one-tenth of that before the change was made, and led also to the institution of some experiments to determine the relative corrodibility of copper, brass, and iron in normal brine and similar brine saturated with air. Though the test cannot be regarded as absolute, since so many conditions affect the corrosion, they possess an interesting relative value, and clearly show the aggravated effect of air saturation in all cases, and therefore the need of so designing brine or ammonia refrigerating apparatus that air, entrained or in solution, may be avoided as far as possible.

Stone Dust for Preventing Explosions in Mines.—At the recent meeting of the Institution of Mining Engineers held in London, Dr. W. E. Garforth, the president, in the course of a paper on "Stone Dusting for the Prevention of Colliery Explosions," said that those colliery owners and officials who had witnessed the stone dust demonstrations and seen the application of the same inert dust on 20 miles of underground roadways during the past four years, considered his mines to be secure from a coal dust explosion. If the expectations regarding the efficacy of the stone dust be realised, coal mining would be as safe as metalliferous mining. The method most successful was distribution by hand, as, by this means, the dust could be better directed, and that with requisite force to dislodge the coal dust and replace it by stone dust. The total cost of stone dusting in a large colliery raising over half a million tons a year would be less than one-tenth of a penny per ton of coal produced, or an annual cost of about £200. In the course of time precautions against the danger of coal dust would be looked upon as part of the ordinary routine of the mine, and, if carried out, then mines would be in a safer condition than ever.

COPPER IN STEEL—ITS INFLUENCE ON CORROSION.

In a paper read before the American Chemical Society, Mr. D. M. Buck gave the results of a series of tests made by him to establish the value of small amounts of copper in steel when exposed to natural corrosion and under atmospheric conditions. To avoid the possible uncertainty in comparing different heats of steel with and without copper, and in order that the conditions, except the copper content, should be identical, it was decided, for these comparisons, to copperise portions of heats, leaving other portions of the same heats in their original conditions. Three heats were used, one consisting of regular basic open-hearth steel of the following analysis: Carbon, 0·10 per cent.; manganese, 0·34 per cent.; sulphur, 0·034 per cent.; and phosphorus, 0·019 per cent. A second basic open-hearth heat was rephosphorised, giving this analysis: Carbon, 0·13 per cent.; manganese, 0·45 per cent.; sulphur, 0·036 per cent.; and phosphorus, 0·042 per cent. The third heat was regular Bessemer steel of the following analysis: Carbon, 0·08 per cent.; manganese, 0·46 per cent.; sulphur, 0·07 per cent.; and phosphorus, 0·096 per cent.

In pouring the open-hearth heats, several ingots were first cast without the introduction of copper; then to four ingots, sufficient copper was added to obtain in two of them about 0·15 per cent., and in the other two, about 0·25 per cent. copper in the finished product. The Bessemer heat was treated in exactly the same way, except that, since the average Bessemer heat was too small to furnish six ingots of the size desired, only two ingots were copperised, aiming at the same contents as in the case of the open-hearth. The copper was added to the moulds, a little at a time, as they were filling and that the resultant steel was uniform in its copper content was demonstrated by many analyses of the bars and of the finished sheets. Indeed, that copper easily diffused through the bath of molten steel, and did not segregate on cooling, was a well-established fact. Six ingots were then taken from each of the open-hearth heats, two normal, two with 0·15 per cent. copper, and two with 0·25 per cent. copper, and three ingots from the Bessemer heat, one normal, and one with each content of copper. The 15 ingots thus prepared were carried through the usual mill operations, each bar as cut and each sheet as rolled having been chalk-marked so that no confusion could possibly occur, and each lot was again carefully analysed as a double check on the operations.

One ingot of each grade of open-hearth steel was rolled into 16-gauge and the other into 27-gauge sheets, 30in. by 96in., while one-half of each Bessemer steel ingot was rolled into 16 and the other half into 27-gauge sheets. All grades were subjected to exactly the same treatment, being rolled by the same crews, and annealed in the same furnaces at the same time, and the finish was such as to conform with that of the competitive sheets used in this test. From 24 to 36 sheets of each of the nine grades, both gauges, making 18 lots in all, were then sheared to 24in. by 96in., thus obtaining a strip 6in. wide from each sheet. These strips were sheared into 2in. by 4in. test pieces, stencilled with distinguishing marks, and were used for the corrosion tests. The 24in. by 96in. sheets were corrugated in the usual way, and eight to 12 sheets of each grade were shipped to each of three testing stations, viz., one in the Pennsylvania coke regions, where the air contained notable amounts of sulphurous and sulphuric acids and other fumes from the coke ovens. In this district iron and steel, unless protected, corroded very fast; another at Atlantic City, where the air carried sodium chloride; and the third in a rural community, where the air was quite pure and free from added corrosive agents.

At each of these locations a skeleton wooden building, 40ft. by 80ft., was erected, with a sloping roof at an angle of about 18°, with the low side about 6ft. from the ground. The buildings were entirely open and free to the passage of air on all four sides, and the roofs were uncovered until the sheets were put on, the purlins being 92in. apart, thus allowing for a 2in. hold on each end of the sheets. The sheets were arranged in panels, each grade being separated from the other by an open space. Open spaces were left between each course, so that the drip from one row did not run on to the row below.

In addition to the nine grades previously mentioned, there were purchased in the open market 27 and 16-gauge sheets of the following average analysis: Carbon, 0·02 per cent.; manganese, 0·03 per cent.; sulphur, 0·034 per cent.; phosphorus, 0·003 per cent.; copper, 0·06 to 0·07 per cent. These sheets were exposed at each of the test stations at the same time as the others and under identical conditions. All of the sheets were placed on the roofs during November, 1911, and were entirely unprotected by paint or other coating, except the thin film of oxide always present on an annealed sheet, allowing natural corrosion to start immediately and to proceed without interruption. The 16-gauge sheets were placed on one-half of the roof, and the 27-gauge on the other half.

The sheets at all of the test stations were examined from time to time by the writer and other independent inspectors, and within a short time after corrosion had started the higher copper steels were showing to better advantage than the other grades. Panels 1, 4, and 7, which contained no copper, were rough to the touch and an examination of the surface of the steel under the rust gave evidence of well-developed pitting. Panel 10, the low carbon and manganese material with only 0·07 per cent. copper, was not quite so rough, and the pitting not quite so well developed, while panels 2, 3, 5, 6, 8, and 9, which contained 0·15 to 0·34 per cent. copper, were fairly smooth to the touch with scarcely any pitting. An interesting fact was noted regarding the colour of the rust on the various panels. The oxide on the non-copper steels was a bright red and loosely adherent. That on panel 10 was a little darker, while the copper-bearing steels carried a dark brown, closely adhering oxide. It was possible to distinguish them by their colour at a considerable distance from the building.

On June 27th, 1912, the non-copper panels, 1, 4, and 7, located on the roof in the coke regions, were failing and falling off, having rusted entirely through. All of the copper-bearing steels were still in excellent condition. On December 7th, 1912, the non-copper panels, 1, 4, and 7 had entirely disappeared, and panel 10, the low-carbon and manganese material, had failed to the extent of dropping off. All of the copper-bearing panels were still intact, and would last several months before ultimate failure. This roof was again inspected early in March, 1913, and panel 10 had entirely disappeared, while all of the copper-bearing steel sheets were still in place.

On September 7th, 1912, the panels on the Atlantic City roof were in about the same condition as those in the coke regions were some months earlier. Unfortunately, a few weeks after these sheets were placed, an unusually severe gale ripped off all of panel 9 and parts of 7, 10, 3, and 6. While none of the copper-bearing materials had failed up to the present time at either of the two roofs located at Atlantic City and in the rural district, yet panel 10 at both places was in very poor condition and would fail very soon, much before the other copper-bearing steels, thus checking up the results obtained in the coke regions.

At the same time that the large sheets were exposed, a series of 2in. by 4in. test pieces, cut from the same sheets, were carefully weighed on a chemical balance, then mounted in wooden racks, with free access to the weather, and exposed at each station. Six pieces of each grade, each piece from a different sheet, were used in this test and a duplicate set prepared and exposed after first removing all surface oxides. After a suitable time had elapsed, and certain of the test pieces had rusted entirely through, they were taken down and reweighed, after first removing all rust by a solution of ammonium citrate, which took off the oxide without attacking the underlying iron. In every case the steels with copper additions showed a marked resistance to corrosion as compared with the non-copper steels, having on the average nearly twice the life. There appeared to be very little difference between the grades containing 0·15 per cent. copper and those with 0·24 to 0·34 per cent., while the material with low carbon and manganese and with 0·06 to 0·07 per cent. copper took an intermediate position between the copper-bearing steels and those without copper.

Accelerated acid tests also were made on the 2in. by 4in. test pieces, from the same sheets as were used in the corrosion tests. The copper-bearing open-hearth and Bessemer steel resisted the acid from 50 to 100 times as well as the non-copper steels, and within the limits of the copper contents of the steels used in this test, the resistance to the acid was directly proportional to the amount of copper present. In this regard the acid tests differed from the actual weather tests. The copper-bearing steels resisted the atmosphere from 1½ to 2 times as well as the normal steels without copper, and there was little or no difference in the average between a copper content of 0·15 and 0·30 per cent.

The writer had never tested a normal non-copper-bearing steel, or iron, which had any marked resistance to the action of sulphuric acid, neither had he found a single instance where steel carrying between 0·15 and 1 per cent. of copper did not show a very marked resistance to the same acid, and the presence or absence of copper was strongly indicated by the solubility of the steel in sulphuric acid. Inasmuch as a copper content also increased the resistance to atmospheric corrosion, a certain relation was established between the accelerated acid test and natural corrosion when comparing copper-bearing with non-copper-bearing steels or irons. On the other hand, many instances had been noted and published where the results of acid tests had been directly opposite to results given by the same steels in service. In the author's opinion the accelerated acid test used for the purpose of determining the values of steels or irons in their resistance to corrosion was untrustworthy and was liable to be misleading.

It was a well-known fact that copper was electro-negative to iron, and when placed in contact with iron it would stimulate corrosion in the latter element. That the reverse was true when the copper was alloyed with the iron and in solid solution in the crystal grains, might be due to the alloy taking, in a measure, the non-corrosive properties of the copper. It had also occurred to the writer that the alloy of copper and iron was less electro-positive to the first film of rust formed than was non-copper steel, and the consequent decrease in difference of potential lessened the corrosion.

It had been suggested by Dr. W. H. Walker that copper prevented the oxides of manganese and iron, which might be present, from coming out of solid solution as the melt cools, and hence, although the oxides were still present, they were held uniformly dissolved, and not segregated between the iron crystals, as was normally the case. Sufficient work had not been done to form definite conclusions, and it was not the intention of this paper to discuss this phase of the subject at length, but rather to give results which seemed to prove that a small copper content in steel, approximately 0·2 per cent., materially increased the life of steel sheets when subjected to atmospheric corrosion.

NEW ELECTRICAL PLANT AT POPLAR.

THE extensions of plant at the electricity station of the Borough of Poplar, which were begun early last year, were officially opened last week by Mr. H. R. Barge, chairman of the Electricity Committee. The additional plant comprises two turbines by Messrs. Willans & Robinson, Ltd., coupled to two 3,000 kw. General Electric Company's alternators, a 1,000 kw. Westinghouse rotary converter, and a motor converter of similar capacity by Messrs. Bruce, Peebles, & Co., accommodated in an engine-room having an area of 4,170 sq. ft. Overhead there is a 30-ton electric travelling crane with a span of 58ft., supplied by Messrs. Royce, Ltd., while underneath the ground level there are two condensers each with 10,000 sq. ft. of cooling surface, motor-driven air pumps of the Edwards type, and circulating pumps by the Rees Roturbo Company. A main switchboard has been provided by the Westinghouse Company. In the new boiler-house, which has an area of 3,555ft. and is designed to accommodate four boilers, each of an evaporative capacity of 36,000lbs. an hour, two Babcock & Wilcox water-tube boilers of that size have been installed and fitted with superheaters to raise the temperature of the steam to 530° Fah. One is supplied with fuel by two underfeed stokers and the other by two stokers of the chain-grate type. The coal supply is obtained from an overhead bunker of 400 tons capacity, to which the coal is delivered by a conveyor by the New Conveyor Company, capable of delivering 40 tons an hour when running at 45ft. a minute. Other plant includes roto-feed pumps by Messrs. G. & J. Weir, softening plant by Mr. William Boby, and circulating water pipes by the Stanton Ironworks Company. The extension has been carried out to the designs of Mr. J. Horace Bowden, the borough electrical engineer.

Department of Mines, Ottawa, Canada.—The Mines Branch of the Department of Mines has, we are informed, installed at Ottawa a modern and well-equipped laboratory for purposes of experimental concentration and metallurgical tests with Canadian ores and minerals. It is expected that the plant will be ready for operation by the first week in July. All communications regarding tests are to be addressed to Mr. Eugene Haanel, Ph.D., Director, Mines Branch, Department of Mines, Ottawa.

TEST OF AN OIL-FIRED WATER-TUBE BOILER.

THE results of a test on an oil-fired water-tube boiler, rated at 450 h.p., and equipped with a superheater, are given by Mr. A. L. Menzin, in "Engineering News." The boiler is one of eight of the same size and type recently installed in the new power station of the U.S. Navy at Mare Island, California. The plant in this station is utilised for furnishing compressed air and electric power about the navy yard, and includes two 5,000 cub. ft. steam-driven air compressors, two 500 kw. and one 1,000 kw. turbo-generators. The boilers were supplied by the Edge Moor Iron Company, of Edge Moor, Del., and the efficiency at about rating guaranteed by them was 80 per cent. Other important guarantees referred to moisture in the steam passing into the superheater, and to steam used by the oil burners for atomisation. All guarantees were met in the first series of tests, the principal data and results of which are given below.

The tests were made under the direction of a board of naval officers, and the contractor was represented by Mr. Menzin. Owing to the pecuniary penalty involved, great care was taken to assure the reliability of all readings. The correctness of the testing apparatus was determined by suitable methods by, or in the presence of, representatives of both the Government and the contractor. The water was weighed in all the tests. In the test for efficiency, the fuel oil was weighed; in other tests, in which the oil used was not involved, the oil was measured with a calibrated piston-type meter.

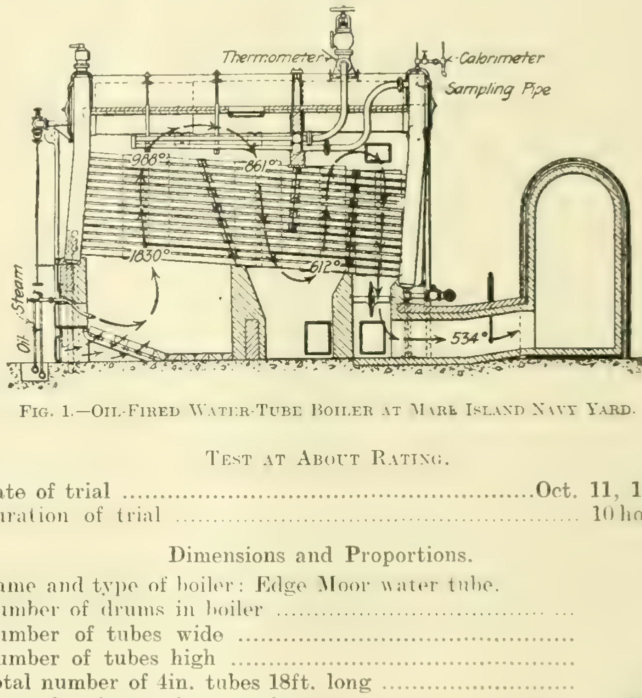


FIG. 1.—OIL-FIRED WATER-TUBE BOILER AT MARE ISLAND NAVY YARD.

TEST AT ABOUT RATING.

Date of trial	Oct. 11, 1912
Duration of trial	10 hours

Dimensions and Proportions.

Name and type of boiler: Edge Moor water tube.	
Number of drums in boiler	2
Number of tubes wide	17
Number of tubes high	14
Total number of 4in. tubes 18ft. long	231
Water heating surface, sq. ft.	4,585
Name of superheater: Foster.	
Superheating surface, sq. ft. (external surface of tubes only)	222
Name and type of oil burners: Owens inside mixer.	
Number of burners to one boiler	3
Area of air spaces in furnace floor, approx., sq. in.	1,140
Area of air spaces per horse-power of rating, approx., sq. in.	2·5

Average Pressures.

Barometer, in., Hg.	30·15
Steam pressure by gauge, lbs. per sq. in.	145·6
Pressure of oil to burners, lbs. per sq. in.	47·5
Force of draught at damper, in. water	0·19
Force of draught in ashpit, in. water	0·15

Average Temperatures (Fah.).

Of external air	70°
Of air passing into ashpit	82°
Of steam	455·4°
Of feed water entering boiler	170·8°
Of escaping gases from boiler	421·0°
Of oil supplied to burners	127·1°

Fuel.

Kind of: California crude oil.	
Specific gravity, oil freed from water, grit, and other foreign matter	0·9501
Gravity, Baumé scale	17·30
Percentage by weight of water in oil	0·12%
Percentage by weight of grit and other foreign matter in oil	0·034%
Calorific value of 1lb. of pure oil with water vapour due to hydrogen content uncondensed, B.T.U.	17,605
Calorific value with water vapour condensed (heat value as commonly given), B.T.U.	18,790

Quality of Steam.

Percentage of moisture in steam passing into superheater	0·06%
Superheat of steam passing out of superheater (Fah.) ...	89·9

Hourly Quantities and Rates.

Pure oil consumed, lbs. per hour	1,008·1
Water evaporated, lbs. per hour, corrected for discharge through calorimeter	13,939·8
Equivalent evaporation, lbs. per hour from and at 212°...	16,001·5
Equivalent evaporation per hour from and at 212°, lbs. per sq. ft. of water heating surface	3·49
Factor of evaporation	1·1479

Horse power.

Horse-power developed	463·8
Rated horse-power (10 sq. ft. of water heating surface per horse-power)	458·5
Percentage of rating developed	101·2%

Economic Results.

Water apparently evaporated under actual conditions, lbs. per lb. of oil as fired	13·77
Equivalent evaporation, from and at 212°, lbs. per lb. of oil as fired	15·80
Equivalent evaporation, from and at 212°, lbs. per lb. of pure oil	15·87
Equivalent evaporation, lbs. per lb. of oil based on a standard calorific value of 18,500 B.T.U.	15·62

Efficiency.

Efficiency of boiler based on calorific value of oil with water vapour due to hydrogen content uncondensed	87·1%
Efficiency (as ordinarily given) based on calorific value of oil with water vapour condensed	81·6%

Smoke Observations and Gas Analysis.

Gases issuing from stack were just barely visible during entire test	
Minimum percentage of CO_2 at damper by Orsat apparatus	12·5%
Maximum percentage of CO_2 at damper	13·4%

Steam Required by Burners.

Steam used by burners to atomise 1lb. of oil as fired	0·321b.
Percentage of steam generated used by oil burners for atomisation	2·33%

For determining the steam used by the oil burners the orifice method was employed. A hole made with a $\frac{5}{16}$in. drill in a common pipe plug constituted the orifice. This was located in the flange union between gauges. The apparatus was calibrated with tank and scales in the usual manner before the tests were run. The Government detailed men from its testing laboratory and engineering departments at Mare Island to observe and record all readings. The contractor also furnished two men for duty on the weighing platform, so that all weights could be certified to by a representative of each party. In the efficiency test, the weighing was conducted so that the weights of oil and water used during each hour could be determined. Pressures, temperatures, &c., were recorded every 15 minutes.

All tests were made on one boiler selected by the Government after the installation was completed and in operation. The blow-off piping and feed-water piping to boiler and superheater were disconnected from respective headers to avoid errors from leakage. The factor of evaporation, equivalent evaporation, and efficiences given above are based on Marks and Davis' steam tables (1912 edition), and are slightly lower than the corresponding official results on account of the high specific heat of superheated steam specified in the contract. This was given as 0·65, which conforms to older practice.

The efficiency obtained in this test is remarkably good, especially when it is considered that the firing was done by the regular Government fireman, who depended entirely on his eyesight for guidance in making the adjustments necessary for good combustion. He was cautioned about the firing probably not more than three or four times during the entire 10-hour run. The essentials for efficient performance, viz., low temperature of outgoing gases and high percentage of CO_2 at damper, were present.

It will be noticed that two efficiencies of the boiler are given. These are in terms of the calorific values of the oil with water vapour due to the hydrogen content uncondensed and condensed as determined by the chemists. For commercial purposes it would seem to be more logical to consider the efficiency based on the first-named calorific value, since the latent heat in the steam produced by the combustion of the hydrogen content is not commercially available for making steam. To utilise this latent heat would require a reduction of the temperature of the flue gases to 212° Fah. or less, which does not seem to be feasible even with economisers. When the fuel used is relatively low in hydrogen and the efficiency of the boiler is based on the "high" heat value, the boiler is unfairly favoured by having a smaller amount of unavailable heat charged up to it. A comparison of boiler efficiencies based on the high heat value of the fuel is, therefore, not sufficient for determining the comparative performance of steam boilers.

It has been pointed out (Trans. Am. Soc. M. E., Vol. 33, page 68) that there appears to be no exact relationship between the hydrogen content and the specific gravity of California oils, and that individual analysis is necessary. Very few data bearing on this point seem to have been published, but, from those available, it would seem that there is a sufficient variation in hydrogen to warrant taking it into consideration when making guarantees, especially when a bonus or penalty is involved.

Besides the test for efficiency at rating, other tests of short duration were made to determine the characteristics of certain parts of the equipment at different rates of evaporation. The percentage of moisture in the steam passing into the superheater as determined by a throttling calorimeter was found to be 0·22 per cent. at 196 per cent. of rating, as against 0·06 per cent. at 101·2 per cent. of rating. The performance of the superheater is shown in the following table:—

Percentage of rating developed	61·4%	101·2%	196%
Superheat	92° F.	90° F.	118° F.

The superheat produced by a given superheater depends not only on the rate of evaporation, but also on the character of combustion. With a given rate of evaporation too little or too much air will affect the average temperature of the gases passing through the superheater and the superheat will be affected accordingly.

The following table shows the steam used by the oil burners for atomisation:

Horse-power developed by one burner	94	155	238	300
Pressure of oil, lb. per sq. in.	39	47·5	78	84
Temperature of oil, F.° ...	127	127	91	90
Efficiency of boiler	...	81·6%	...	...
Steam required for atomisation, lb. per lb. of oil ...	*0·30	0·32	*0·20	*0·17
Percentage of steam generated used by burners for atomisation	2·4%	2·33%	1·8%	1·5%

*Oil measured by meter and weight computed.

The steam used by an oil burner depends, of course, within limits, on the care taken by the fireman in adjusting the steam valve. This adjustment is not a delicate one, and if a fireman is careless he can use a great deal more steam than is required—which is not only a waste but which may also cause damage to the tubes by blowing the flame up against them. The inside mixer type of burner is somewhat proof against such carelessness, as too much steam raises the pressure in the mixing chamber, which cuts down the supply of oil and therefore the fire.

Fig. 1 shows the fall of temperature of the gases through the boiler when operated at about 196 per cent. of rating. Temperatures taken with the boiler operating at about rating would probably be of more interest, but, unfortunately, a complete set of readings was not taken during this test. How-

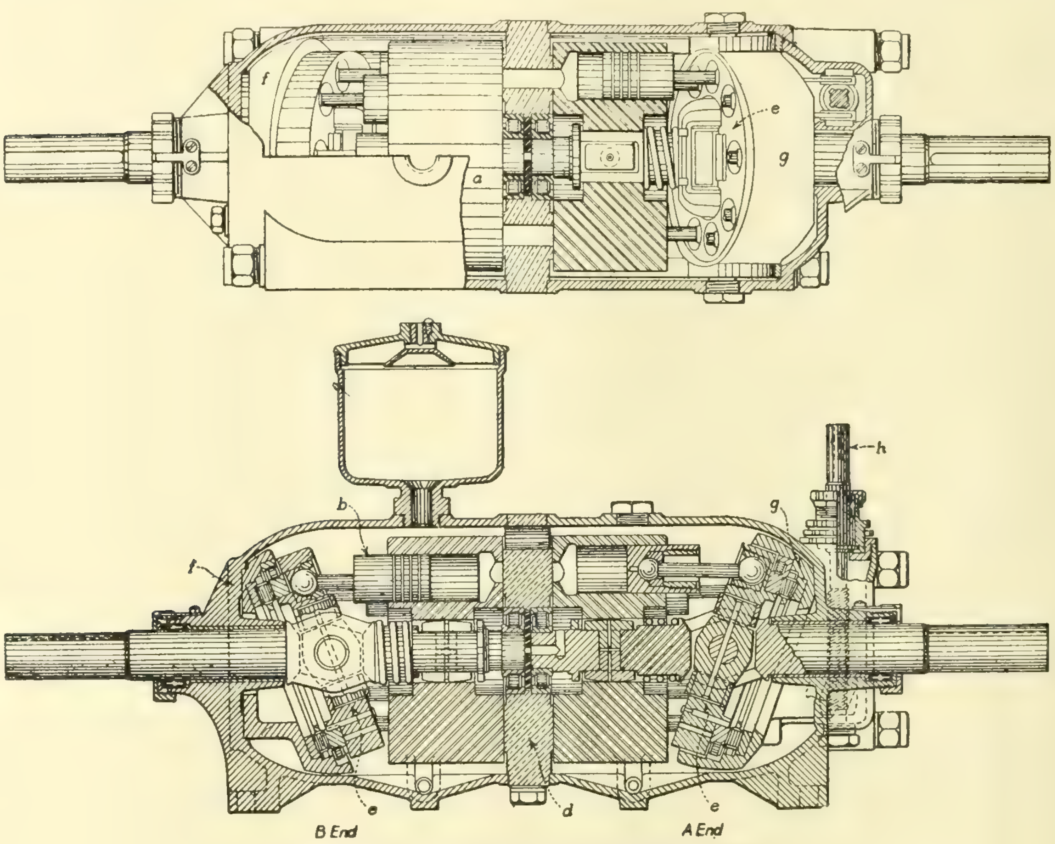
ever, those taken permit of a comparison of the temperatures at certain points, which is given below:—

Percentage of rating developed	101·2%	196%
Temperature between 1st and 2nd rows of tubes over furnace, F.	1560°	1830°
Temperature at top of first pass	686°	988°
Temperature of gases passing out of boiler	421°	534°

The temperatures given above are the averages of several readings. All temperatures in the setting were taken with a Bristol electric pyrometer with bare thermo-couples set at approximately 30in. from the inner face of the boiler wall. The thermo-couples were set by trial to give the highest temperatures, which corresponds to a setting where the cooling effect of radiation from the thermo-couple to the tubes is a minimum. All temperatures taken with the pyrometer are corrected for air temperature at the junction of the fire end with the extension piece. The temperature of the outgoing gases was taken with a mercury thermometer, located as shown in the drawing. Temperatures near the damper, taken with the pyrometer, practically agreed with those indicated by the mercury thermometer.

A NEW HYDRAULIC TRANSMISSION GEAR.

THE Waterbury Tool Company, Waterbury, Conn., has brought out a hydraulic-power transmission gear, which has been tested out for two years on men-of-war for elevating guns and controlling turrets. Apart from this field, these gears are applicable to automobiles, cars, draw-bridges, cranes, hoists, machine tools, and the propelling of vessels. The particular features about the gear are a compact arrangement, the use of a somewhat novel method for automatically preventing leakage between the parts of the device, the lubrication of the various parts, the absence of any transmission of side pressure, and the use of a special design of roller bearing and universal joint connections. The gear is shown in the accompanying sectional views, for which, along with the following description, we are indebted to our American contemporary, "The Iron Age."



SECTIONAL VIEWS OF HYDRAULIC TRANSMISSION GEAR.

The complete transmission device is made up essentially of two parts, an oil pump designated as the A-end, which may be driven by any source of power, and is supposed to run at a constant speed in one direction, and an oil engine designated as the B-end. By the turning of a small control shaft connected with the A-end, the stroke of the pump pistons is varied at will to deliver oil to the B-end at a rate necessary to give the required speed in the direction called for. The B-end is constructed to furnish a constant cylinder capacity per shaft rotation, and the speed of the B-shaft is definitely determined by the rate at which oil is supplied by the pump. The speed ratios between the two shafts are positively and definitely determined by the angular position of the control shaft in either direction with reference to its neutral position.

The two ends are combined into one working unit, the power entering by the A-shaft, which rotates at a constant speed, and is taken out by the B-shaft at the opposite end, which rotates at any required speed and in either direction. The small vertical shaft shown at the A-end is the control shaft, and the direction of rotation of the B-shaft is determined by the direction the control shaft is rotated from its zero position, and the speed of rotation is determined by the angle through which the control shaft has been turned. On top of the B-end is an oil expansion box communicating with the oil in the machine. The whole enclosing shell of the gear is filled with oil, although only a small portion of the oil is under pressure and active in transmitting power. In this type of gear the two ends are united by a valve plate, which is located across the middle of the machine, and through which the oil is circulated between the two ends. This valve plate can be made in almost any shape, permitting the placing of the two ends at any angle or in any position with reference to each other. Each end can be provided with a separate valve plate, located in any desired position, the oil circulation being provided for by connecting pipes. Passing through the valve plate about half-way between its centre and periphery are two semi-annular passages for the circulation of oil between the two cylinders. When the gear is transmitting power one of these passages is under pressure, while the other is in suction, the functions being changed according to the direction of rotation of the driven shaft.

There are three pairs of valves connected with the passages. At the top are two small needle air valves used only for the escape of air from the passages and cylinders while they are being filled with oil. At the bottom there are two ball check valves used for replenishing any leakage that may take place from the high-pressure oil to the low pressure, and at the bottom, near the replenishing valves are two safety valves to provide relief if the gear should become overloaded. There is also a plugged hole connected with each passage near the top for attaching gauges to measure the oil pressure or the load carried. Near the top of the valve plate, and also in connection with all the valves, are holes passing through the plate, giving free circulation of oil between the two ends of the gear.

The shaft groups of parts in the two ends are almost identical. A cylinder barrel, *a*, is keyed rather freely to the inner end of each shaft and is able to slide. Each of these barrels has nine cylinders parallel with the shaft and fitted with piston *b*, having ball-ended connecting rods. The faces of the barrels slide in their revolution against prepared faces on the valve plate *d*, and the cylinder ports in the barrel faces register with the semi-annular passages, except as they

are passing over the separating lands at the top and bottom of the plate.

The barrels are held lightly against the faces of the valve plate by spiral springs around the shaft, which are compressed between shoulders on the shaft and counter-bored recesses in the barrels. These springs are intended only to hold the barrels in position under no load, and when the gear is transmitting power the barrels automatically support themselves. The connecting rods are formed with a ball on each end, one ball end being secured in a piston and the other in a socket in the socket rings *e*, these rings being connected by special universal joints with the shaft. In this way, while the rings revolve with the shaft, their planes of revolution may be at any angle to the shafts, the angularity being controlled by the setting of the roller bearings on which the socket rings revolve.

In the B-end of the gear the socket ring *e* runs in what is called an angle box *f*, that is secured in the end of the case itself through which the shaft passes. It stands at a fixed angle of 20°, thus giving a constant reciprocation to the B-pistons. In the A-end the box is hung on trunnions, and may be adjusted to any desired angle, while the gear is running by turning the threaded control shaft. The connection of tilting box *g* with control shaft *h* is clearly shown in the drawing, and as the load on the trunnions of the box is practically a balanced one the turning of this shaft is easy.

The A-shaft which is connected with the source of power is supposed to run at a constant speed and in one direction. If the tilting box *g* stands in its vertical or neutral position at right angles to the shaft, the pistons are carried around with the cylinder barrel but do not reciprocate, and no oil, therefore, is taken from or delivered to the passages in the valve plate. If, however, by turning the control shaft *h* slightly the tilting box is inclined, the pistons reciprocate approximately to the extent of the sine of the angle of tilting multiplied by the diameter of the circle of centres of the sockets in the socket ring.

Every cylinder during one-half of the shaft rotation is in connection with one of the passages in the valve plate and is then receiving oil, which it carries across the land and delivers into the other passage during the other half of the shaft rotation, the amount of oil thus transferred depending entirely upon the piston displacement. There can be no transfer unless there is a supply to draw from and a space to deliver it into, and these are provided by the cylinders of the B-end. When oil is being forced into one of the passages which is already filled the pistons in the cylinders of the B-barrel in communication with this passage make room for the oil by sliding back from the valve plate, but they cannot do this without forcing their respective sockets in the socket ring farther from the valve plate. This can only be done by turning the socket ring as a whole in its inclined plane.

It should be remembered that the B-socket ring, unlike the A, is always inclined at 20° in its angle box, so that the B-pistons always reciprocate to their full extent at every rotation of the B-shaft, while the pistons facing the high-pressure passages of the valve plate are receding to make room for the incoming oil and so imparting rotation to the B-shaft, the pistons facing the low-pressure passage are moving toward the valve plate and delivering the oil from their cylinders through the low-pressure passage into the suction cylinders of the A-barrel. Since the receiving capacity of the B-cylinders is constant and the delivery capacity of the A-cylinders is varied at will by turning the control shaft, the speed of the B-shaft is correspondingly changed. It will be seen that the only oil actively employed in transmitting power is that in the oil passages of the valve plate, and cylinders.

The oil pressure in the cylinders and valve plate passages varies directly as the torque resistance which the B-shaft must overcome. The horse-power transmitted varies directly as the product of the oil pressure and the speed of rotation of the B-shaft. The normal working oil pressure ranges usually between 300lbs. and 500lbs., but it may rise to from 1,000lbs. to 2,000lbs. to overcome an unusual resistance, and in tests, pressures as high as 4,000lbs. per sq. in. have been reached.

One of the principal advantages of this type of transmission is its flexibility. The B-shaft may be started under a dead load of any magnitude within the strength limit of the machine without any fear of overloading the motor or source of power, and the speed may then be gradually increased up to a maximum. As a result of this flexibility, it is pointed out that the efficiency varies widely. Under the best conditions, efficiencies ranging from 85 to 91 per cent. are common, while under average working conditions the efficiencies vary between 80 and 85 per cent. Under small loads and low speeds of the B-shaft the efficiencies vary from 80 per cent. as a maximum down to 50 per cent. or lower. At a zero speed the horse-power efficiency must, of course, be zero, while the torque efficiency remains at 95 per cent. In this way the horse-power efficiencies have a wide range from zero to 91 per cent., while the torque efficiency throughout the whole range remains between 90 and 96 per cent.

BOOK REVIEWS.

The Year Book of Wireless Telegraphy. London: The Marconi Press Agency. 8½in. by 5½in., 563 pp. Price 2s. 6d.

If this volume does not quite accord with our conception of what a year book should be, it is not so much on account of lack of material as of excess, and, having regard to the quality of much of it, perhaps few readers will grumble. The book opens with a calendar and a concise chronological record of progress in wireless telegraphy since 1896. The next section gives the London Convention of 1912, as well as the laws and regulations of the principal countries concerning wireless telegraphy. This is followed by a complete list of land and ship stations of the world, with their call letters, ranges, wave lengths, and the nature of the service, hours of opening and changes, all set out in an easy form for reference. Other features are an article by Mr. Arthur R. Hinks, M.A., on "Wireless Time Signals"; another on "Distress Signalling," by Mr. G. E. Turnbull, is particularly strong, and some of the leading experts have contributed. Prof. J. A. Fleming, F.R.S., Dr. W. H. Eccles, Capt. H. Riall Sankey, and others are among the authors of signed articles. Major J. E. Cochrance, with military wireless telegraphy, and Dr. J. Erskine-Murray, with wireless telephony. In addition, there is much valuable technical data, and a very full glossary of technical terms in English, French, German, Italian, and Spanish. A valuable feature of the book is a new and revised map of wireless stations of the world.

* * *

Principles of Setting Out, Securing, and Tooling Operations for Engineering Students and Apprentices. By Alfred Parr. London: Longmans, Green, & Co. 9¼in. by 6in., 290 pp. Price 7s. 6d. net.

The increasing use of machine tools in the manufacture of accurate repetition work has made the work of setting out and jig and template making of greater importance, and no works manager can be considered accurately equipped unless he is familiar with this kind of work. For this reason it is the more imperative that the aspiring engineering student should be familiar with the principles of it. "At one time," as Prof. Bulleid observes in an introduction to this volume, "setting out meant covering a casting or forging with whitewash and drawing in the lines with a scribing block on a table. Now it involves, in addition, the use of special fixtures for holding the work on the machines, jigs for drilling through, and templates and gauges for setting the tools and testing accuracy, since many articles are finished without a single line being drawn on them. The man who sets out such work must be well acquainted with the proper tolerances and allowances for various classes of fits, as well as with the best methods of holding work and the proper cutting speeds." Simply studying a book cannot, of course, make a man an expert where different jobs call for the exercise of fresh thought, and often permit of more than one method of solution, but it is possible by carefully-selected examples to illustrate the general principles, and this the author has succeeded in doing in an admirable way.

SOME FUNDAMENTAL FAULTS OF PRESENT-DAY FURNACES AND THEIR REMEDIES.*

BY ALLEYNE REYNOLDS.

(*Concluded from page* 629.)

Heat Balance-sheet of an Open-hearth Steel-melting Furnace.— In forming a heat balance-sheet of a steel-melting furnace, no account must be taken of any exothermic or endothermic reactions inherent to the process conducted in the furnace, those ordinarily given in text-books being worse than valueless and very misleading. Even were they properly established, they would be balance-sheets taken between the air inlet of the producer and the cast output of the furnace when cold. As a matter of fact, chemical reactions in steel manufacture are not merely reciprocal, but actually reciprocate. The law governing them must be that of least temperature disturbance.

But what use can calculations be which entirely overlook such trifles as the latent heat of carbon? The author has what he considers ample proof that the reaction between silicon and oxide of iron ceases to be exothermic at steel-making temperatures, and that the carbon reaction may be exother-

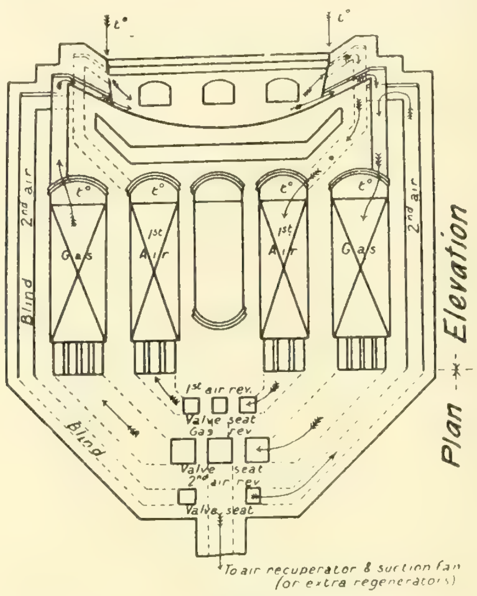


FIG. 6.

mic. When the effect of specific and latent heats is intelligently taken into account, it at once becomes apparent why the feeblest reducing agent, carbon, becomes, ultimately, the most powerful at high temperature. The specific heat of carbon rises with increasing temperature, the fastest of all oxidisable substances. Hence even endothermically-formed carbides require less temperature disturbance for their formation than the elements from their oxides by carbon reduction. The balance-sheet taken in respect of a melting furnace must be one concerning the amount of heat expended in useful work in the furnace, and taking no account of loss of heat in the ladle and in the mould during casting.

The energy at disposal is the whole energy due to complete combustion of fuel, as shown by the calorimeter. This is made up as follows: Total combustible value of constituents of the fuel, less energy required to gasify them.

At any intermediate stage of combustion the total available heat of the fuel may be divided up into three items, as follows:—

Sensible heat of gas	A
Combustible value of gas	V
Radiation, &c., losses in producer and flues	Z

Total (say K) = A + V + Z = calorific power of fuel.

A + V would equal K if Z = zero, and depends solely on the proportion of the total air required for complete combustion which had been used as primary air for gasification. But Z increases with A, and hence the lower Z is the greater A + V and the less A, so still the greater V. Therefore, by artificially usefully lowering A, Z can be lowered and A + V increased. A means of doing this is to pass steam in with the primary air, which is decomposed, lowering temperature, but, with a given ratio of primary air, can have no effect on the ratio of secondary air required to burn the resultant gas. It has, however, the effect of creating a diluent of high specific heat in the products of complete combustion, thus lowering the potential calorific intensity of combustion. There exists then an absolute guide to the working of a producer. The value of V must be made a maximum by using the minimum amount of primary air, and as much steam as can be completely decomposed should be used in the producer.

A true sample of the coal to be used should be burnt in a calorimeter and its calorific power ascertained, and the products of combustion from the calorimeter should be analysed, so as to ascertain the ratio of hydrogen to carbon in the coal. Analytical tests should be made of the products of combustion of the fuel, with various air ratios, so that the minimum excess air should be ascertained. The fixed carbon contents of the coal should also be ascertained, and then the ratio of primary to secondary air can be finally fixed. From an analysis of the products of combustion the amount of steam which had been used in the producer could be ascertained.

Before proceeding further in regard to increasing the value of A + V, we must study the balance-sheet of an open-hearth steel-melting furnace taken at the reversing valves. Such a balance-sheet consists of the following items:—

Heat Balance-sheet, Open-hearth Steel-melting Furnace.

Input at Gas-reversing Valves.	Calories.	Output. Work done and Losses of Energy.		Calories.
Sensible heat of gas	A	Energy derived from combustion of a portion of gas and air requisite to raise products of partial combustion to temperature of heated charge		D
Heat added thereto by gas regenerator	B	Heat radiation of port blocks	U	
Heat imparted to air by air regenerator	C	Heat added to charge	W	E
Combustible value of gas......	V	Heat transmitted to charge but lost by radiation from hearth	X	
		Heat lost by radiation of roof and walls of combustion chamber	Y	
		Replacing B		B
		Replacing C		C
		Radiation of both gas chambers	RG	R
		Radiation of both air chambers	RA	
		Loss in waste gases............		F
		Loss of gas each reversal......		G

Total....A + B + C + V = D + E + B + C + R + F + G.

The following should be carefully noted: The quantity of heat required to melt, smelt, and superheat the charge and slag is a fixed and definite amount dependent on the process adopted and material charged. The loss in waste gases, and of gas on reversal (other than leakage unnecessarily taking place) is proportional to the fuel burnt. The loss in radiation is proportional to time and temperature. The heat receptivity of the charge is also a function of time. Radiation losses must be allocated to different headings according to their relation to the regenerative or other parts of the furnace system.

The port blocks or ends of the furnace down to the regenerators do a minute portion of regenerative work, which, for reasons previously given, is negligible as to utility, but it must be remembered that, as the heating surface is small in ratio to the radiating surfaces of these portions of the furnace, the heating surface may have its temperature rapidly elevated, and, owing to relative heat absorption of this portion being so very small, it naturally is most liable to overheating. Its radiation loss has been made a separate item in consequence, and this portion of the furnace is treated as not a portion of the regenerative system. The radiation losses of the roof and side walls, and of the hearth. have been

* Paper presented at the annual meeting of the Iron and Steel Institute, May, 1913.

made separate items as the relative receptivities of heat differ, and it may be necessary not to reduce the former too much in order to avoid overheating locally.

The sum of the items B + C + R + F cannot be below the amount which is the sensible heat of the products of combustion at the temperature of the charge. It must also not be of an amount that makes the sensible heat of the waste gases involve too high a temperature for the structure of the ports, whose heat absorption is so very small.

The temperature of the waste gases cannot be below a certain amount, that is, less than that due to a sensible heat equal to A *plus* the amount of heat rendered latent for regenerative purposes, owing to difference between the sensible heats of the constituents and products of combustion.

Owing to this, the sum of B + C + R + F must be greater than the sum of A + B + C by an amount greater than R, so that some combustion must take place within the regenerator chambers. This again takes place between gas and air, which have been pre-heated to the temperature of the maximum temperature of the flame over the charge, and the heat receptivity of the ports being generally lower than that of the charge, they become in consequence the hottest portions of the furnace system. The lower the temperature of the regenerators, the larger item D becomes. The skilled melter is then faced with a whole chain of incompatible conditions, and how skilled he really is will be better appreciated when these are reviewed.

In an ordinary steel-melting furnace, unless B and C be large, D will be large, and for W to exist at all, there must be a minimum value for B and C. There is only one way theoretically possible. The melter must reduce D, and he must artificially reduce B + C + R + F. He does this by reduction in the amount of C, by not passing enough air for combustion of the gas through the inlet air regenerators, and letting the balance in direct from the atmosphere through the charge door next the exit ports. The diminution of C in quantity, without lowering intensity, reduces D considerably, whilst producing the requisite quantity of energy by combustion of gas, with not over-heated air in the ports. This enables him to obtain generation of energy simultaneously with its absorption within the regenerators.

The method is crude, and ought to be carried out on scientific lines. The means of doing so constitutes a portion of one of the author's inventions. His furnace is provided with an additional recuperative or regenerative system, in which a portion of F is used to heat air delivered to the air regenerator chamber, thus reducing C. In addition, a three-way reversing valve system and suitable connections deliver heated air from the recuperator or extra regenerator, or cold air, as desired, to the upper zones of the outlet regenerator chambers, so that combustion not being allowed to take place within the outlet ports, the latter cannot be overheated. This furnace is illustrated in Fig. 6.

Where the excessively high temperatures of a steel-melting furnace are not required, the regenerators may be allowed to become as hot as the charge, and item D rendered nil, while C is much cut down, thus allowing a neutral or even reducing atmosphere within the furnace charge chamber, so that ingots may be heated for rolling without scaling, bronzes be melted without oxidation, or even ores reduced, and pig iron be very economically melted.

The appearance of item D has a doubly pernicious effect, as will be seen from Fig. 7, which clearly shows in part sectional elevation and plan, an ordinary type of open-hearth steel-melting furnace. The point at which item D has brought about the requisite flame temperature is suggested by an arrow. Now, dependent on the position of this point, is the ratio of actual heating surface of the bath to its radiation surface, and hence this decides the vital issue of the ratio of W to (X + Y). The author, therefore, set about inventing a means of removing the double influence of D on W. The invention will be understood from Fig. 8.

In one form of his furnace the usual gas regenerator chambers are divided into a large gas and small air-regenerator chamber, and the usual air regenerator chambers are divided into a large air and small gas-regenerator chamber, each pair of chambers having its own regulating and reversing valve systems, there being thus two gas and two air reversing valve systems. Also, the hot waste gases, instead of being led into a chimney, are led into an air recuperator or regenerator. Thus, item D is made to take place, under full control, within the gas and air ports of the furnace. The arrangement in Fig. 6 for letting in cool air into the outlet chambers may be added if necessary.

All gas-regenerating forms of furnace, however, possess an objectionable feature, namely, item G. This may not be wholly lost where recuperators are used, but the lapse of time when W = nil is really a serious item of loss. Gas-reversing valve leakages are a serious cause of inconvenience and damage, as well as loss of fuel. Clearly, then, great advantages must accrue if gas regeneration can be avoided, and items B and G disappear from the balance-sheet.

There is again another very important consideration. In steel-melting furnaces, the brickwork is "seasoned" by iron vapours given off, which become oxidised into Fe_3O_4, and increase the refractoriness of the bricks. But the hot producer-gas reduces this to FeO, thus fluxing the brickwork in the gas regenerators and ports. In the author's furnace (just described) this influence would be lessened, but by abandoning gas regenerators it would vanish, and the air regenerators

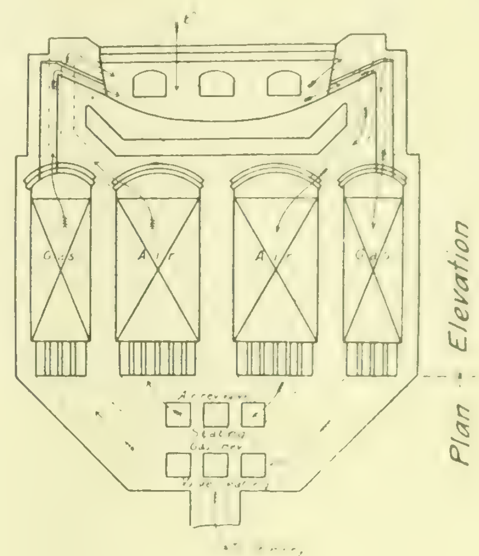


FIG. 7.

could be worked to as high temperature as the charge. So long then as item D can be made to take place in the ports, especially if reduced in amount, a large gain will have resulted. If the air be allowed to become as hot as the charge—and there is no objection to this—combustion of the gas within the gas port only will be required to supply item D. The following invention of the author's enables this to be achieved (see Fig. 8). In this, the usual gas regenerators and gas-reversing valve are used for that portion of the air supply required to produce item D. Of course, a separate three-way gas-reversing valve system is provided, and suitable leads to the gas ports. Recuperators or additional regenerators are also provided, as indicated, but not illustrated. In this furnace the balance-sheet can be absolutely modified as desired.

B is, of course, deleted from both sides, and F may be reduced to such an amount in theory that the unavailable heat of CO_2 becomes no longer fully unavailable. A very peculiar set of conditions is then established. A may be theoretically doubled, or at anyrate V be increased by an amount equal to A, by employing a portion of the recuperator or extra regenerator to heat the air-blast of the producer, and using more steam in the producer. C is increased owing to the higher temperature permissible in the regenerators. D would suffer to the extent of B and gain to the extent of increase in C. C + R + F could be exactly the right amount.

Thus, if increase in C = B, then there exists a large gain, added to by elimination of G.

Assuming the gas to be pure air gas, there will be for 2,881 cubic metres of air gas containing 1 cubic metre CO, and air containing 0·8 cubic metre O_2, the following figures:—

Open-hearth Furnace.

Input.		Calories.	Output.	Calories.
Sensible heat gas at 500	A =	470·2	Raising gas and air from 1200° to 1600°, rendering some heat latent ...... =	—
Raising same to 1200 ..	B =	751·6	Main portion of D........	1110·0
Raising air to 1200	C =	1615·7	Balance	4790·5
Calorific power of gas ..	V	3063·0		
Total		5900·5	Total	5900·5

Reynolds' Furnace (Fig. 8).

Input.		Calories.	Output.	Calories.
Sensible heat gas at 500°	A =	470·2	Raising gas from 500° to 1600°	1229·6
Raising air to 1600°....	C =	2247·7	Balance	4551·3
Calorific power of gas ..	V =	3063·0		
Total		5780·9	Total	5780·9

It will be perceived later that the greater deductions for losses from the former, much outweigh the lower balance in the latter.

The author is well acquainted with the working of two batteries of open-hearth furnaces, the one acid and the other basic, the former belonging to one of the greatest and most justly celebrated English firms, the latter to an equally great and justly celebrated continental firm. The managers are men whom the author believes to be unsurpassed in skill and ability by any in the world. The furnaces are certainly not worse designed than any of the present day. Yet the English furnaces consume 9 cwts. of good coal per ton of steel, whilst the continental burn 4¾ cwts. to 5 cwts. of bad coal per ton of steel. It is certainly favouring the English firm if it be assumed that with the English coal at the continental plant they would only burn 4½ cwts. The continental furnaces are tapped every six hours, the English every 12 hours. The charges are in each case about 50 per cent. each of pig and scrap, and the basic furnaces are run on low phosphorus pig.

It may be assumed with some certainty that the absolute heat units required to melt and smelt 1 kilogramme of steel in each case, together with its accompanying slag, is about 400 calories. Taking the fuel at a calorific power of 8,000 calories per kilogramme, there is in each case 0·05 kilogramme of coal required to melt and smelt the steel and slag. The loss of energy in waste gases and between air inlet of producer and reversing valves is about 50 per cent. of the fuel, and so in each case radiation losses of the furnace may be derived.

	Continental. Kilogrammes.		English. Kilogrammes.
Work done	0·05	..	0·05
Loss in waste gases, and in producer and gas flues	0·1125	..	0·225
Balance radiation	0·625	..	0·105
Total	0·225	..	0·450

This appears a shocking result in the English furnace. Let us, however, look more closely into the conditions in the light of our synthetically reasoned balance-sheets. In each case it takes a certain time to raise the charge to 1,200°, and another certain time to raise it to 1,600° and fuse it. Up to this point the furnaces behave much alike. But the continental furnace is engaged on structural steel, which is quickly run down soft and is not dead melted, so about two hours suffices for the process. The English furnace is hard run on steel dead melted as far as possible. It has to be run eight hours after reaching 1,600°, as high oxygen contents of the bath are not permissible in an acid furnace, and for quite one to two hours an endeavour is made to dead melt, that is, deoxidise the steel.

During the first four hours, then, about 100 calories per hour per kilogramme is required in each case. During the first period D = zero, and so any decent furnace will do the same work. But in the succeeding hours perhaps only 5 calories per hour per kilogramme are required. Then is the time that elimination of D yields its great saving, when the radiation losses are deliberately made very large in relation to W. High potential of a flame entering the furnace at high temperature must shorten the melting period and yield some economy.

Let us take then the average work of the continental furnace, translating the figures into work done by 0·538 kilogramme pure C., which yields 1 cubic metre CO_2, evolving 4,344 calories. Let us assume pure air gas to be produced, and the waste gases to issue at 600°, and the products of combustion to contain CO_2 and O_2 in the ratios of 10 to 3, thus each 1 cubic metre CO requiring 0·8 cubic metre O_2 for its actual combustion.

Assume the regenerators to be run up to 1,200°. A trial balance-sheet can then be made as follows:—

Balance-sheet, Average Working of Continental Furnace.

A......................	470·2	D		361·6
B......................	751·6	W		965·3
C	1615·7	U		
V......................	3414·1	X		
		Y		1206·7
		G		
		R		
		B	.... 751·6	
		C	1615·7	.... 3718·0
		F	....1350·7	
Total	6251·6		Total	6251·6

In the foregoing a fictitious value has been given to V, such fictitious value being derived as follows: With air gas the sensible heat would be 821·3 calories, but with the actual

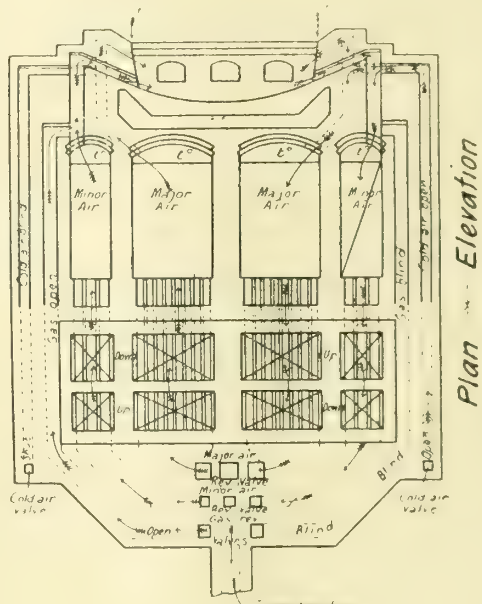


FIG. 8.

gas only 470·2 calories, so the difference has been added to V, making the latter 3,414·1 calories in lieu of 3,063 calories.

From the above can be calculated approximately the working of the furnace at the dead-melting period. Item G demands attention first. This can be influenced in a variety of ways, but obviously it should bear relation to the amount of radiation to maintain a constant temperature drop between reversals. The practice is to make more frequent reversals the higher the temperature, and really there is much to be said for this. At the time D becomes a large item, temperature drop becomes the more serious. Taking the average, and putting 100 reversals per unit gas as the stock heat, so that the heat charge in the chambers equals that of 100 times the unit of gas, or 50 times that amount at each end of the furnace, some 4 per cent. drop of heat charge takes place each reversal period. Taking this as a basis, the average value of G may be estimated as follows:—

Assuming, as in the balance-sheet, that 751·6 calories per unit gas are taken from the gas regenerators each reversal period, and they each require a stock of heat = 50 units heat,

then the stock in each gas chamber becomes $50 \times 751 \cdot 6$, or 37,580 calories per unit gas. This has to be stored up in bricks at a mean temperature equivalent to, say, 1,000°, and of a specific heat of, say, 0·3, or, say, 300 calories per kilogramme brick. Thus, the weight of brick would be $\frac{37,580}{300}$ kgs. (or 125·27 kgs.). One cubic metre of brick weighs about 2,240 kgs., thus the volume of brick required per unit gas would be, say, $\frac{37,580}{300 \times 2240}$ cubic metre, or about 0·056 metre. Taking then the spaces to be 2·881 to one brick, so that the volume of CO equalled that of the brick, $3,414 \cdot 1 \times 0.056$ calories or 291 calories would be lost each reversal. This estimate is rendered the more reasonable, as it takes no account of the really serious loss due to valve leakage. Including valve leakage, the amount may be safely put down at, say, 306·7 calories.

Assuming, however, that the spaces are less than 2·881 times the volume of the bricks, it will be quite reasonable to put the loss due to reversal at 206·7 calories minimum, and as reversal occurs oftener when the furnace is hotter, this figure may be regarded as a constant. This gives, on the average, $U + X + Y + R = 1,000$ calories.

As an estimate, it is reasonable to suppose the radiation, &c., loss of the portions above the regenerator chambers as 60 per cent. of this, thus making $R = 400 \cdot 0$ calories. Then $B + C + R + F = 4,118 \cdot 8$ calories, corresponding to a temperature of between 1,500° and 1,600°. In other words, the mean temperature involved is one not damaging to the furnace. As the temperature of the charge rose, so as to require 1,600° on the slag, F would have to be increased. But the loss on reversal is a sudden loss, represented by an average, so that the actual temperature of the waste gases for most of the time would be that due to 4,324·6 calories or 1,600°. But when the furnace is dead melting, that is, when W is required to be nil, the conditions are much altered. By combustion the gas and air have to be raised from 1,200° to 1,600°, and in doing this some heat is rendered unavailable in CO_2. The mere raising of the gas and air to 1,600° would require $478 \cdot 0 + 632 \cdot 0 = 1,110 \cdot 0$ calories, or the combustion of $\frac{1110 \cdot 0}{3414 \cdot 7}$ unit of gas containing 1 cubic metre CO, so to the above figure must be added the amount of heat rendered unavailable at 1,600°; this would be about 130 calories, making $D = 1,240$ calories.

The foregoing balance-sheet would then become as follows:—

Continental Furnace Dead Melting.

Input.		Output.		
A	470·2	D		1240·0
B	751·6	W		nil
C	1615·7	U		
V	3414·1	X		652·1
		Y		
		R	434·8	
		B	751·6	4152·8
		C	1615·7	
		F	1350·7	
		G		206·7
Total	6251·16	Total		6251·6

The foregoing might, at first sight, be held to indicate that the furnace in question was an apparatus admirably capable of fulfilling all requirements, save and except that one would desire to reduce items F and G with a view to economy. But we must now consider not merely the establishing of a balance-sheet, but whether a balance-sheet is capable of being maintained at all by such a furnace. In this connection we must consider the rather difficult matter of heat-absorption-capacity of the bath. This is not only directly but indirectly affected by the metallurgical process taking place therein. The temperature gradient when "dead melting" is quite altered by the chemical reactions, which are of 100 per cent. efficiency in their influence on the bath of metal. It is only by their being of 100 per cent. efficiency that they take place at all.

The exothermic reactions require absence of very high temperature for their occurrence, and the endothermic reactions the presence of high temperature. These two influences then cause the temperature gradient to be uniform throughout the bath so long as enough reacting elements are present. A ferruginous slag is probably a fairly good heat conductor.

Again, as FeO in the slag is combustible into Fe_3O_4 and Fe is combustible by Fe_3O_4 into FeO, catalytic reactions tend to cause oxygen to be transferred indirectly from the furnace gases to the charge of steel, the more rapidly in the basic than the acid process, because the FeO in the former is in solution in, and in the latter a somewhat stable chemical compound of, the slag. It may be seen, then, that the temperature of the steel may be much affected by management of the process. The action of large lumps of ore which cause some direct reaction between Fe_2O_3 or Fe_3O_4 and the constituents of the bath, must be very different to that of small lumps which go into solution in, or combination with, the slag.

Again, an enormous influence is exercised by the question of whether reaction takes place between combined or uncombined carbon and iron oxide. The process should be run to enable the carbon to be first combined before being oxidised, so that the carbon oxidation stage of the process is not so endothermic. To enable this to be done, the charge must contain ingredients the oxidation of which causes great evolution of heat, or the charge must be shielded from oxidation until it has been charged with enough heat to make the carbon combine. For this reason, *inter alia*, charges only work well in which due ratios of silicon and carbon are present when first melted down.

The effect then of chemical reaction is to remove temperature gradient from the heating surface of the metal to the interior surface of the hearth, and thus considerably to increase the heat receptivity of the bath, and render the furnace heating capacity much more effective. The author first realised this in 1896, and on making use of the obvious deduction therefrom, considerably surprised those associated with him. He had to make an ingot from three acid furnaces, and one of them had a "hard tap-hole." In spite of burning so much gas that the unfortunate furnace had some 6in. or more of the port blocks fused off, in spite of frequent reversals and every dodge known to skilled workers, during the two or three hours the hard-working men tried to tap the furnace, using sledge-hammers, the charge rapidly cooled down, until only about 15in. depth of steel below the slag remained molten. During this period the author hit on the theories just expounded, and charged the furnace with some siliceous and carbonaceous pig iron and iron ore. In some 10 minutes the charge tapped itself out. After this practical proof of his theory, he obtained permission to make further deliberate trials thereof. A certain proportion of pig and scrap in the charges in the best working furnaces always gave the best results, and he then took care to obtain the same composition when a different charge was melted down. Thus, even using 93 per cent. scrap, with additions of 10 per cent. ferro-silicon and over 4 per cent. carbon pig, so that the charge when fused was the same composition as if ordinary charges had been used, gave the same result not only in quantity of ore and time required, but resultant tests of the steel produced. The Talbot process itself is somewhat analogous in its principle of starting from a given ratio of pig and scrap after each pouring.

Perhaps the author may at this juncture be allowed to make an interesting digression. For the making of high-class steels in which welding up blow-holed ingots is unthinkable, it will probably not be found of any use to search after an ideal much sought after by many, that is, going to additional cost and trouble to produce unpiped ingots. Until semi-steels can be produced in the blastfurnace or other raw-material-producing furnace, it will probably always pay, in fact, be essential, to have charges containing the percentage of scrap now produced owing to the piping of ingots.

It may be seen, from what the author has alluded to in regard to the influence of chemical reactions on the temperature gradient, that a furnace may be readily capable of producing (with a given heating surface in relation to bulk of charge) a steel nearly refined of its oxygen. But such a furnace may be quite incapable of maintaining such a charge

molten in the absence of such influence on its temperature gradient.

Here it is, then, that most furnaces fail. Owing to the item D causing serious diminution of the ratio of heating to radiation surface of the charge, and the heat-conduction capacity of the slag and metal depending on the relative potential calorific intensity of the flame and charge, it is not possible at high temperatures to force through the slag enough heat units to provide for X, and W becomes negative in consequence. The use of more gas results in additions to the stock of heat in the regenerators, and diminution in D, but the rapid stocking of heat in the regenerators causes serious local over-heating of the ports and regenerators. Here, then, comes in the great importance of the author's principle of safety causing item D to take place within the entrance ports.

Supposing, in the author's continental instance, that at a temperature of 1,600° the item D takes place at such a point that only three-fourths of the slag surface becomes heating surface, and that when the furnace is maintaining constant stock heat at 1,200° maximum in the regenerators that W = 200 calories, then, when dead melting, the sum of radiation losses would be increased by that amount, that is U + X + Y by 120 calories, and R by 80 calories. Owing to the increased heating surface due to making D take place within the ports at the entrance end 4/3 more heat units could be forced

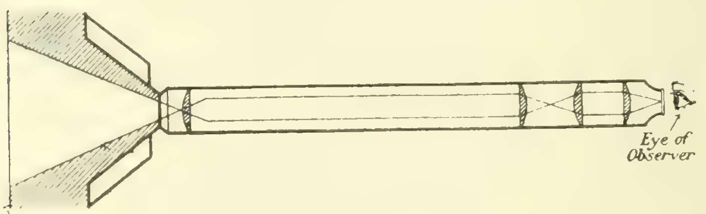


FIG. 9.

through the slag and U + X + Y be reduced by 25 per cent. The dead melting conditions would be as follows: In the furnace as at present

$$U + X + Y = 652{\cdot}1 + 120 = 772{\cdot}1,\ W = -20.$$

In the furnace with item D occurring within the ports

$$U + X + Y = \frac{3 \times 772{\cdot}1}{4} = 579{\cdot}1,\ W = 772{\cdot}1 - 579{\cdot}1 \times 20 = 172{\cdot}1.$$

In the one case it could not maintain the charge molten, in the other it could rapidly superheat it. Supposing, however, in the furnace in question, the regenerators were allowed to be run at 1,600°, so as to eliminate item D from the balance-sheet, the effect would be as follows when W = nil:—

B + C would be increased by amount = D, and U + X + Y + R by a like amount, namely, R by an amount = $\frac{1240 \times 4}{10}$ 496 calories. Thus R + B + C + F would equal 4,152·8 + 1,240·0 + 496·0 or 5,888·8 calories, corresponding to a temperature of over 2,000° C. Such temperatures are, of course, out of the question. Producer gas at 1,600° would ensure the formation of iron silicates with a fusion point of well under 1,500° in the brickwork, and the bricks will not stand a temperature of above 1,800°, even when impregnated with Fe_3O_4. By working one of the author's furnaces so that the flame at its entrance into the furnace is maintained at 1,600°, the calorific intensity is maintained high, and thus the heat absorption capacity is also maintained at a high figure, admitting of a large gas consumption and small radiation loss. The charge may be so superheated that the chemical reactions when they occur do not absorb heat, or at anyrate not to such a degree. Thus, more rapid working and much better deoxidation become possible, producing not only economies in fuel and repairs, but admitting of the production of steels of far better quality. Much less skill and care would be required in working such a furnace than one of the ordinary type.

Enough has been written to show the very serious defects of the ordinary open-hearth furnace, and to indicate the class of alterations and additions required thereto. When the objectionable hot chimney is dispensed with, regeneration may be carried as far as desirable. All that is necessary is that the regenerators should require an enormous amount of heat to be stored up in them, and that from the lighting up the furnace, reversals should take place the moment the waste gases arrive at a certain temperature. Metal regenerators should be used for the lower temperature zones, and the ratio of surface to volume of each regenerator unit should be inversely as the temperature. By reducing the temperature of the outlet gases 25 per cent. economy of fuel may be secured.

By maintaining combustion within the inlet ports the full surface of the bath becomes available as heating surface, so that an average economy of some 40 per cent. to 50 per cent. in fuel could be secured in steel-melting furnaces. It is well to realise what a poor and hampering device to secure draught a hot chimney is. At 600° C. the products of combustion of pure air gas (1 cubic metre of $CO + 1{\cdot}881$ cubic metre of N_2) would be 1 cubic metre of $CO_2 + 0{\cdot}3$ cubic metre of $O_2 + 4{\cdot}891$ cubic metre of N_2, or a total of 6·191 cubic metres of gases, with a sensible heat of 1,350·7 calories, or 126 h.p. The buoyancy in a very tall chimney would be a bare 2in. of water.

The worst suction fan on the market would produce a higher buoyancy than the entire energy of the fuel at a very small fraction of the power expenditure. The effect of slight positive or negative pressure has a distinct influence on the carbon reaction, as may be perceived from the frothing up of slag on reversal. Thus many advantages may accrue from being able to control these influences better by means of powerful mechanical draught.

Physical laws demand a minimum of excess air being required to allow combustion to become quite complete, besides which, lack of difference in directions, and velocities of gas and air streams, hinders physical contact between the constituents of combustion, and causes further surplus air to be required. Small furnace ports, with inlet gas and air under pressure, are therefore necessary to lower the excess air required, and high suction power to exhaust the gases of combustion through them.

Several years ago the author had considerable experience in working furnaces he had designed for vertically heating very long forgings for hardening. These furnaces had air inlets into the gas ports at the bottom and air inlets at intervals in their height. The heating was more economical and uniform when combustion was allowed to be so incomplete that a long bright flame issued a considerable height into the atmosphere. Some recent experiences with Bunsen gas-burner furnaces using illuminating gas were, however, even more instructive. With air at 2lbs. per square inch a temperature of only 1,450° C. was obtainable, but with air at 10lbs. per square inch a temperature of 1,550° C. was reached. With the inverse type of burner, with the gas at 50lbs. per square inch, a temperature of 1,600° was reached, proving that there was a very minute excess of air above that required to satisfy the chemical equations involved.

Under the best working conditions interesting physical phenomena manifested themselves. Groups of molecules of gas and air met so sharply that the flame "roared" and a green ray appeared in it, the latter being due to the carbon and hydrogen of the hydrocarbons being brought into such violent contact with oxygen that it hardly admitted of the production of incandescent carbon and hence the green ray—at least that is the author's explanation of it. It appears (he is informed) when porcelain burners are used, and is not due to combustion of copper or other metals.

It should be noted that by opening a furnace door the furnaceman upsets the working conditions of his furnace and deceives himself as to what is normally taking place therein. The furnace should be provided with sight-holes (water-cooled where necessary) and closed from the atmosphere by means of glass or mica. It may be too hot in their neighbourhood for the furnaceman to place his eye close to them, and he should be provided with an optical instrument to overcome this. The author mentioned this to a friend, who told him that such instruments are employed to enable the captains of dirigible balloons to observe the engines as if they were close to them. The class of sight-hole and telescope required are diagrammatically illustrated in Fig. 9.

In conclusion, the author would point out that his furnaces are all based on the types of construction shown or indicated in Figs. 6 and 8 in conjunction preferably, and in some cases necessarily, with his controlling devices, illustrated in Figs. 1 and 2, and already described.

In all cases the main (high temperature) regenerative system may be one in which the waste gases issue at a fairly high temperature, say, 600° C., and may be, and preferably are, further cooled in an additional air regenerative or recuperative system not shown in the diagrams. If the former, it will require a four-way reversing valve system for the hot, and another for the cool gases.

Mechanical forced draught is employed for the primary and secondary air, and preferably also for suction of the waste gases.

If air regeneration alone is required (as is the case in steel-melting furnaces, where the temperature required is too high to render gas regeneration other than disadvantageous), the furnace may have its main regenerators extended, as shown in Fig. 8, and the outlet gases may issue at a very low temperature therefrom. It will have the double set of air regenerators and air-reversing valves, to provide for combustion of gas within the gas inlet port, as shown in Fig. 8, and the provision for leading air into the exit chambers. The regenerators are in all cases run at as high a maximum temperature as is required by the charge.

When a very strongly reducing flame is required in the working chamber and the maximum temperature admits thereof, the furnace is provided with gas regenerators and takes the form shown in Fig. 6, and is provided with auxiliary air regenerators or a recuperator.

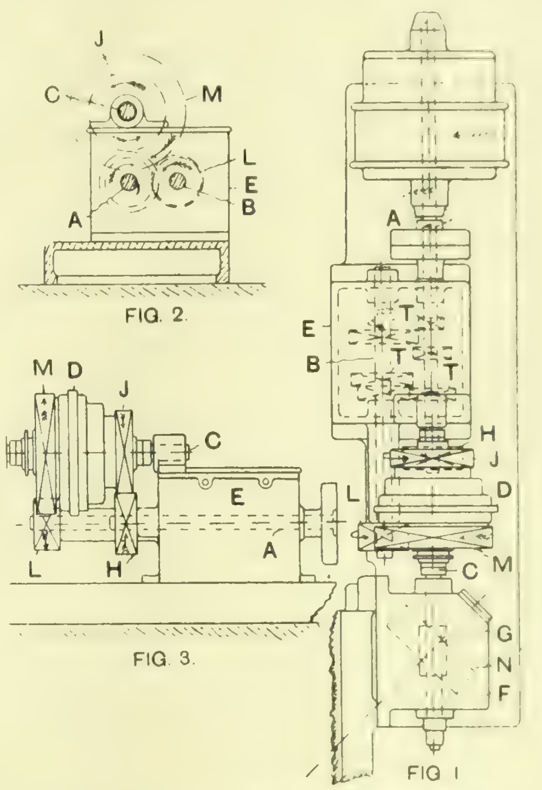
When oil is the fuel used, the vaporiser is heated by hot waste gases from the main regenerators of either form of furnace indicated by Figs. 6 and 8, and the waste gases from the vaporising chamber are led into an auxiliary regenerative system or recuperator for heating the air led into the main regenerators.

Fatal Crane Accident.—A crane accident of an unusual character occurred recently at the works at Grimesthorpe, Sheffield, of Messrs. Cammell, Laird, & Co. It appears that during the working of the crane the bearings became loose, and one of the rollers flew out, striking a workman on the back of the head with fatal results. The roller weighed about 5¼lbs., and flew about 20ft. At the inquest on the deceased Mr. F. W. Smith, assistant engineer, explained that it was a most unusual occurrence for the bearings of a crane to become loose. He had never before experienced difficulty in this way. The displacement of the bearings must have been caused either by the rollers becoming twisted or that some grit had got in and caused some friction which lifted up the ring holding the rollers in position. It would be possible to prevent a recurrence by fixing a guard on the top of the ring. The usual verdict of "Accidental death" was returned.

Boiler Explosion on a Barge.—Judgment was delivered on Saturday last at Liverpool in the Board of Trade enquiry into the boiler explosion on the steam barge "City of Liverpool," as she was proceeding through the Manchester Ship Canal, near Runcorn, in February, as a consequence of which the engineer was killed. The vessel was owned by the North Lonsdale Iron and Steel Company, of Ulverston, and the boiler was built by Messrs. Stevenson, Ltd., of Preston. The Court found that the customary inspections and tests of the boiler had revealed no leakage. The engineer found a stay leaking while the vessel was at Lancaster in January. He cut the nut off and wrapped the stay with asbestos cord, instead of caulking. This was the first circumstance which brought about the fatal explosion. A subsequent examination disclosed that the stay had been cracked and corroded for some time, a defect which was accentuated by the treatment it received, as the threads were completely worn away. The whole strain of the boiler pressure was thus allowed to come on the stay, which gave way. The cause of the explosion was of rare occurrence, only one previous instance having come to notice. The Court further found that neither the owners nor the insurance company were to blame.

DRIVING AND REVERSING GEAR FOR PLANING MACHINES.

THE arrangements of driving and reversing gear for planing machines, illustrated herewith, have been designed and patented by Messrs. Joshua Buckton & Co., Ltd., Wellhouse Foundry, Leeds, in conjunction with Mr. C. W. James. Fig. 1 shows a plan view of an arrangement for giving variable cutting speeds with a quick return, whilst Figs. 2 and 3 show, respectively, end and side elevations of portions of the same. On the shaft A, which is uniformly driven from a motor drive or otherwise, is mounted a pinion H. This pinion gears with the wheel J, mounted on an independent shaft C. On the shaft C is arranged a double-ended reversing friction clutch, the central portion D of which is firmly fixed to this shaft. The wheel J and pinion H are so proportioned as to produce a speed suited for a quick return for the gear of the machine table, acting through the central portion of the clutch D. Another pinion L, arranged on shaft B, gears with the wheel M which rotates in the opposite direction to that of the wheel J. This shaft B rotates in the reversed direction to that of the first driving shaft, and has sets of

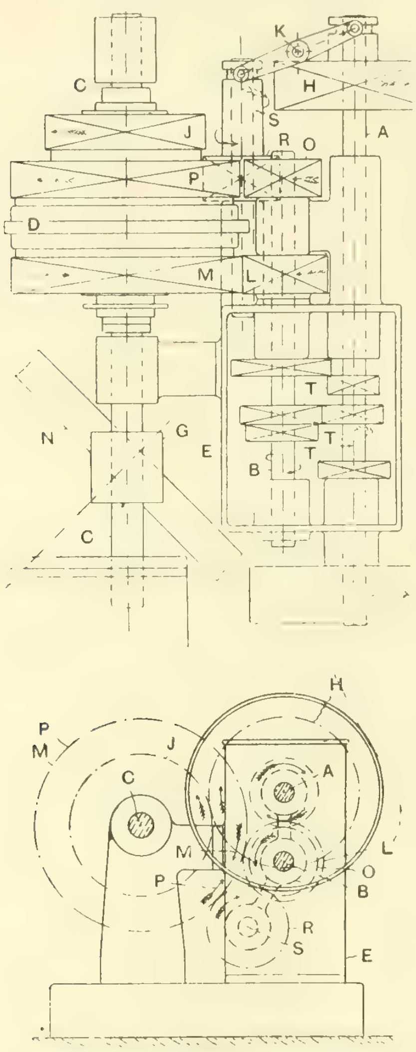


DRIVING AND REVERSING GEAR FOR PLANING MACHINES.

change-wheels thereon for producing (when brought into gear with the first motion shaft) the desired variability in the speeds of the "cutting stroke" of the planing machine. The gear box E is oil charged in the usual way. The clutch shaft is supported on the gear box E, at one end, in the bearing shown, and at the other end in a worm and wormwheel gear box F. In the arrangement shown G is the worm and N is the wormwheel mounted on a slanting shaft. The wheels T, mounted on the shafts, A and B, passing through the gear box E, are suitable in diameter for producing the variable speeds desired for the cutting strokes. It will be noted that the reverse direction of rotation for the shaft B, thus secured by the direct mesh of the change wheels, is that necessary, and made use of for producing the reverse drive—*i.e.*, the cutting drive—of the double-ended reversing clutch, hence the compactness and simplicity of the whole arrangement.

When it is desired to alter the drive to suit a double cutting machine, an additional "idle wheel and axle" is used, so that the variability of the cutting speeds may be supplied in both directions of the table as shown in Figs. 4 and 5. In this case the same drive is arranged, but with

additions, as follows: On the prolongation of the shaft B of the change-speed gear box E is another pinion O, and in order that this shall finally drive the gear in the correct rotating direction with the other oppositely running wheel P (connected with the double-ended reversing clutch as used in the other example) an idle wheel R and axle S is introduced. In this way the correct direction of drive and the desired variability of cutting speeds in both directions of the machine table is attained. In order, however, to retain the "quick return" gear and use it at will, the quick return pinion H and also that of the idle wheel R and axle S (that is, the pinion R of the idle wheel and axle) are mounted, so that they may mutually slide in and out of gear, and so make way for one another. Although no further shaft is required, other than that for the idle wheel R, it it is found convenient in practice for retaining the simplicity of the gear at T, to arrange a second driven wheel J on that end of the clutch which is to be alternatively brought back into use for the "quick return" speed. At K is shown the position of a fulcrum for a lever whose outer ends engage with bosses on the sliding pinions, H and R, for the purpose of putting these wheels or pinions in and out of gear, when a change is made from variable cutting in both directions to variable cutting in one direction with quick return in the other. The sliding pinions are mounted on feathers. The change-speed gear box E has but one necessary secondary shaft B (however many changes may be required), and that one, being in direct mesh with the driving shaft A, produces the requisite reverse motion required for the reverse end of the clutch.



FIGS. 4 AND 5.—DRIVING AND REVERSING GEAR FOR PLANING MACHINES.

Explosion in a Submarine.—An explosion occurred a few days ago in the engine-room of Submarine E 5, which was proceeding to Portsmouth after completion by Messrs. Vickers at Barrow. As a result of the explosion one man was killed and a number of others more or less seriously injured.

Launch of a Cunarder.—The "Alaunia," the latest addition to the Cunard Company's Canadian fleet, was successfully launched at Messrs. Scott's yard at Greenock on Monday last. The launch was to have taken place on Saturday, but had to be postponed on account of boisterous weather. The "Alaunia" is the fourth vessel built specially for the rapidly-developing trade between the home country and Canada. A feature of the ship is that her passenger accommodation will be for two classes only, and the usual first and second classes are to be fused into one class, a standard feature of which will be its remarkable quality. The complement of passengers in this department will be 520, and in the third class 1,620.

THE GAS ENGINE IN THE STEEL INDUSTRY.*

BY HEINRICH J. FREYN.

SINCE 1906, American gas-engine builders have furnished about 500,000 h.p. of gas engines in units above 500 h.p. capacity, the great majority of which are operated on blast-furnace gas. Within the last two years, however, the demand for gas engines seems to have fallen off, and only comparatively few gas-engine installations were put down in this country. It is time to analyse the underlying causes and to endeavour to clear our minds concerning the economic position of the gas engine as compared with that of the steam turbine and the turbo-blower.

Gas engines to-day are used almost to the exclusion of steam turbines and turbo-blowers in German steel and coke oven plants, and the demand for large gas engines is so great that the five foremost engine manufacturers in Germany alone are building such engines at the rate of about 120 per year. To-day we claim the blastfurnace and coke oven plants as the natural field for the large gas engine and the field where its greatest development will lie in the immediate future. In the enormous field of power generation directly from coal in the large central power plants of our cities, the steam turbine is in undisputed possession and will doubtless remain so until the producer gas plant or gas turbine reaches a further stage of development.

Let us assume a blastfurnace plant of eight furnaces of about 450 tons capacity each, producing about 3,600 tons of pig iron per 24 hours. The amount of blastfurnace gas generated in this plant will be 22,500,000 cub. ft. per hour, since it is generally agreed that 150,000 cub. ft. of gas is liberated per ton of pig iron produced per 24 hours. This gas will have an average heat value of 95 B.T.U. per cubic foot. Of this total quantity, about 40 per cent., or 9,000,000 cub. ft., is used for heating the blast in the stoves or lost by leakage.

For gas blowing engines, about 2,600 b.h.p. per furnace are required, which consume, at the rate of 12,000 B.T.U. per brake horse-power hour, about 330,000 cub. ft. of gas per hour, or for eight blastfurnaces 2,640,000 cub. ft. An additional quantity of 460,000 cub. ft. per hour for eight blastfurnaces will be necessary to produce in gas-electric engines the required power to operate the furnace auxiliaries, such as air compressors for mud guns, skip hoists, ore handling machinery, transfer cars, bells, lighting, and so on.

The total quantity of blastfurnace gas which has to be deducted amounts thus to 12,100,000 cub. ft. per hour. In other words, there will remain for use, outside of blastfurnace operation, 10,400,000 cub. ft. per hour. This quantity of gas represents at a heat value of 95 B.T.U. per cubic foot the total amount of heat of 1,000,000,000 B.T.U. per hour.

To make use of this available quantity of heat for power generation, gas-electric engines or steam turbo-generators can be installed. In the former case, the available quantity of heat will produce at the rate of 16,200 B.T.U. per kilowatt-hour at the switchboard, corresponding to an average thermal efficiency of 21 per cent., a total of about 60,000 kw. (90,000 b.h.p.). If this available quantity of heat is converted into power through gas-fired boilers and steam turbo-generators, the maximum capacity of the power plant would be about 30,000 kw. (45,000 b.h.p.) if a heat consumption of 32,500 B.T.U. per kilowatt-hour, or a thermal efficiency of 10·5 per cent., of the steam plant is assumed.

Such conditions exist to-day in this country at Gary in the largest steel plant in the world, where gas-engine generators of a total capacity of about 68,000 kw. maximum continuous rating will be in operation within a few months. During the last year the maximum continuous rating of this plant was 50,000 kw., and the average use factor, including Sundays, was 64·5 per cent. Assuming the same use factor in the future, when the plant capacity will be 68,000 kw., and deducting the Sundays, the use factor for 313 working days would be 76 per cent., so that 52,000 kw. will be generated every working hour to meet the power demands of the steel plant itself and of the allied industries located in its vicinity.

If in this steel plant steam turbines had been installed, only one-half of this power demand could have been covered by burning blastfurnace gas under boilers, so that for the remainder of 30,000 kw., it would have been necessary to use

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steam coal. Assuming a coal consumption per kilowatt-hour of 3lbs. of coal of 10,500 B.T.U. per pound, which would correspond to 10·8 per cent. thermal efficiency at the switchboard, there would have been required $3 \times 30{,}000 \times 24 \times 313$ 676,000,000lbs., or 300,000 gross tons of coal per year. At a price of $2.50 per gross ton as fired, which is the prevailing price in that locality, the total expenditure for coal per year would have been $750,000.

As gas-electric engines were installed in this plant, the requisite additional power of 30,000 kw. is obtained by utilising directly that portion of the available blastfurnace gas which, in the case of steam equipment, it would have been necessary to replace by coal; so that the cost of coal, less the difference between fixed charges and operating expenses per annum of a 30,000 kw. gas-engine plant and a 30,000 kw. steam turbine installation represents the actual annual saving with which the Gary blastfurnaces must be credited.

A gas-engine power plant of the required capacity of 30,000 kw. can to-day be duplicated for less than $90 per kilowatt maximum continuous rating, all legitimate expenses included. A steam turbine plant, with boilers, economisers, superheaters, condensers, pumps, coal and ash-handling machinery, and other auxiliaries for boiler and turbine operation would cost, under steel mill conditions, from $65 to $70 per kilowatt maximum continuous rating.

Figuring on 15 per cent. fixed charges per annum and $70 per kilowatt, there has to be deducted from the gross saving of $750,000 the product $0·15 \times 20 \times 30{,}000$, or $90,000.

The operating expense, without fuel cost or fixed charges, of the Gary power plant in 1912, at a use factor of 64·5 per cent., Sundays included, was 0·0824 c. per kilowatt-hour, delivered at the switchboard. The corresponding expense for a steam turbine installation of the requisite capacity and operating at the same use factor, may be assumed about 20 per cent. lower, so that the excess operating cost of the gas-engine plant per annum would be $0·016$ c. $\times 30{,}000 \times 24 \times 313 = \$36{,}000$, which amount would further reduce the gross saving.

The total reduction to be made from the gross saving is $126,000, and the net saving per year amounts to $624,000. An eight-furnace blastfurnace plant will produce about 1,200,000 tons per year, so that the pig iron account should receive a gas credit of 52 c. per ton, simply because no steam coal had to be fired to cover the power demand. Incidentally, this saving in cost of pig-iron production represents an equivalent saving of national wealth. That is, it corresponds to a quantity of 300,000 tons of coal put aside annually for our children and children's children.

With turbo-blowers installed, the situation would be: The total quantity of blastfurnace gas from eight blastfurnaces, after deducting the gas used for stoves, lost by leakage (9,000,000 cub. ft.) and utilised for power purposes of the blastfurnace plant itself, but without blowing engine requirements, would be 12,600,000 cub. ft. per hour, since for blastfurnace purposes alone, about 900,000 cub. ft. of gas per hour would now have to be used on account of producing the requisite power for the furnaces themselves with steam equipment. The gas consumption of steam turbine-driven turbo-blowers of 2,900 b.h.p. capacity per furnace at 12lbs. of steam of 135 lbs. gauge pressure at the throttle, 125° superheat, 28·5in. vacuum, and 63 per cent. boiler efficiency, would be about 240 cub. ft. of gas of 95 B.T.U. per brake horse-power hour, or approximately 5,600,000 cub. ft. of gas for eight blastfurnaces. The net quantity of blastfurnace gas available for outside purposes would thus be 7,000,000 cub. ft. per hour.

If, now, a steam turbine plant were put down to utilise this quantity of gas for generation of electric power, there could only be produced about 20,000 kw. (30,000 b.h.p.), while the difference of 40,000 kw. between the actual power demand and the power supply by blastfurnace gas would have to be made up by firing coal under boilers. Assuming the same values as previously regarding the thermal efficiency of the turbo-generator plant, there would be required 400,000 tons of coal per year, which, at a purchase price of $2.50 as fired, would be worth $1,000,000 annually.

From this gross saving, the difference in fixed charges and operating expense between gas engine and steam turbine plants must be deducted, as before, so that the actual net saving would amount to $832,000 per annum. The gas credit would now be about 70 c. per ton of pig iron produced.

These figures are nothing short of appalling, and the savings are so tremendous that any argument of gas-engine opponents is silenced. And, no matter what reasonable claims are made in favour of steam turbo-blower and steam turbine equipment for the great steel plant at Gary or any other plant of similar character, the saving, due to the installation of gas engines, remains so stupendous that the old controversy, steam or gas power, is once for all disposed of in favour of the gas engine.

The cost of power production is, however, not the only consideration which should enter into the calculation; for frequently other, not purely financial factors, when put on the right side of the scales, may radically change the ultimate result. Such influences of practical nature, and to which monetary values cannot always be assigned, are, for instance, the upward tendency of the fuel market, the chances for future extension, the direct or indirect bearing of the type of prime mover selected upon other departments of the industrial enterprise for which the equipment is intended, and last, but not least, freedom from irregularities in fuel supply, which may arise from car famine and strikes.

At the Cockerill Works at Seraing, the old, single-acting gas-blowing engines, which were installed in 1900, are still in use. And even the first 200 h.p. blastfurnace gas engine, built at these works in 1898, although of obsolete type, is still performing its work quite satisfactorily. The largest gas engine power plant in the world, that at Gary, has now been in operation over five years, but even the most pessimistic investigator would have to concede that the Gary gas engines are good for at least another term of five years. Seven per cent. depreciation figured on gas engines does not mean that these engines will be useless at the end of 10 years' time because of wear and tear or on account of age or decrepitude, but simply that they must be written off in that time, due to obsolescence. It would not be prudent to reckon with more than 10 years' life of the equipment, because new inventions may revolutionise our present methods of power production so completely that it would be impossible for financial and economic reasons to maintain profitably the old equipment.

The work of reducing the costs on the books to the true figures which can consistently be charged to these plants, is not simple. It was done about two years ago with utmost accuracy for the gas engine installations of the United States Steel Corporation. It was decided to follow the practice customary in steam turbine plant accounting, that is, to base all installation cost figures on the maximum continuous rating of the generator at 40° C. temperature rise. In the majority of cases, the gas engines have a greater capacity in brake horse-power than corresponds to this generator rating, and we agreed to call the maximum continuous rating of these gas engines that kilowatt capacity which at 95 per cent. generator efficiency and 80 per cent. mechanical efficiency, corresponds to a mean effective pressure in the gas cylinders of approximately 70lbs. per square inch, a value which is universally adopted by gas engine builders.

Table I. gives the actual installation costs of a number of gas engine stations in plants of subsidiary companies of the United States Steel Corporation. The figures coincide fairly well, with the exception of those pertaining to the cost of gas cleaning plants. The discrepancies among the latter are entirely due to differences of design and local conditions. The

TABLE I.—*Cost of Installation of Blastfurnace Gas Electric Power Plants.*

Power Plant No.	1	2	3	4	5
No. of unit	17	2	4	4	5
Cap. kw., max. con. rating	40,000	4,500	9,000	9,000	11,400
Cap. b.h.p., max. con. rating	56,400	6,400	12,800	12,800	16,300
Cost of installation per kw., max. con. rating:—					
(A) Buildings......	$9·87	$75·50 (A and B)	$10·17	$10·90	$10·52
(B) Eng. equipment	71·78		72·75	77·78	80·32
(C) Gas cleaning plant	5·85	16·80	14·40	13·00	12·76
Grand total, power plant complete, per kw.	$87·50	$92·30	$97·32	$101·68	$103·60

gas cleaning plants for the smaller installations are much more expensive than that for the larger power plant, because the latter was originally designed with a view of installing gas engines, so that this gas cleaning plant represents the latest and most efficient arrangement; whereas in the others, gas cleaning plant and gas-engine installations had to be fitted into existing plants. Moreover, some of these smaller plants started out with extreme caution in the matter of gas cleaning and provided, in addition to Theisen washers, expensive central power station engineers in this country agree that the cost of a steam turbine power plant per kilowatt maximum continuous rating varies from \$60 to \$100, and it is generally conceded that the average is near \$80 per kilowatt. There are not many lighting or street railway power plants in this country which cost less than \$65 per kilowatt, and the majority of these plants have capacities considerably larger than even that of the Gary gas engine plant, some having as much as 200,000 kw. capacity in steam turbines under one roof.

Table II.—*Cost of Installation of Blastfurnace Gas Blowing Engine.*

Plant No.	1		2		3		4		5	
Number of units installed	16		4		6		4		4	
Capacity installed, B.H.P.	42,000		10,500		14,000		10,500		10,500	
Capacity operating, B.H.P.	31,500		7,875		14,000		8,000		8,000	
Total displacement of operating engines, cu. ft. per minute	360,000		90,000		180,000		90,000		90,000	
Investment per B.H.P. installed:		%		%		%		%		%
(A) Buildings	\$7·87	10·7	\$59·70	88·4	\$8·99	12·0	\$10·69	13·8	\$10·75	12·7
(B) Engine equipment	61·40	83·1			55·20	74·0	60·05	77·3	67·40	79·4
(C) Gas cleaning plant	4·58	6·2	7·88	11·6	10·07	14·0	6·98	8·9	6·79	7·9
Total	\$73·85	100·0	\$67·58	100·0	\$74·26	100·0	\$77·72	100·0	\$84·94	100·0
Investment per B.H.P., operating:										
(A) Buildings	\$10·50	10·7	\$79·50	88·4	\$10·92	12·0	\$14·06	13·8	\$14·20	12·7
(B) Engine equipment	82·00	83·1			70·43	77·0	78·94	77·3	88·90	79·4
(C) Gas cleaning plant	6·10	6·2	11·81	11·6	10·07	11·0	9·19	8·9	7·90	7·9
Total	\$98·60	100·0	\$91·31	100·0	\$91·42	100·0	\$102·19	100·0	\$111·00	100·0
Investment per cu. ft. displacement of operating engines:										
(A) Buildings	\$ ·92	10·7	\$6·97	88·4	\$ ·85	12·0	\$1·25	13·8	\$1·26	12·7
(B) Engine equipment	7·18	83·1			5·47	77·0	7·02	77·3	7·88	79·4
(C) Gas cleaning plant	·54	6·2	1·03	11·6	·78	11·0	·81	8·9	·79	7·9
Total	\$8·64	100·0	\$8·00	100·0	\$7·10	100·0	\$9·08	100·0	\$9·93	100·0
Investment for 500-ton blastfurnace:										
(A) Buildings	\$41,500	10·7	313,300	88·4	\$38,250	12·0	\$56,250	13·8	\$56,500	12·7
(B) Engine equipment	323,000	83·1			246,500	77·0	315,750	77·3	350,000	79·4
(C) Gas cleaning plant	24,200	6·2	46,550	11·6	32,250	11·0	36,750	8·9	36,000	7·9
Total	\$388,700	100·0	\$359,850	100·0	\$320,000	100·0	\$408,750	100·0	\$442,500	100·0

hydraulic fans, baffle washers, and screen washers, with the necessary gas piping. These, however, were subsequently found to be unnecessary and are now inoperative.

All figures give the cost of the so-called secondary cleaning plants only, that is, of that part of the gas washing system which prepares the gas for gas-engine purposes after having been roughly purified in so-called preliminary or primary gas washers. The latter, however, would be part of a steam turbine installation as well, because it was recognised that blastfurnace gas should be purified at least to a certain degree of cleanliness, even for stove and boiler purposes.

In Table II., the cost of installation of gas blowing engines in the same plants is given. To obtain a uniform basis for comparison, it is assumed that each furnace is blown by three tubs or 1½ gas blowing engines in all plants under consideration, and requires 45,000 cub. ft. per minute displacement of air. The maximum continuous capacity of all engines was based on this quantity (30,000 cub. ft. displacement per engine) and 25lbs. blast pressure. The rating of all engines was determined assuming 18lbs. per square inch mean effective pressure and 90 per cent. mechanical efficiency of the air tubs themselves, with the exception of one plant, where high-speed gas blowing engines are installed.

It can be seen from these cost figures that the equipment with high-speed gas-blowing engines is a good deal cheaper than that of slow-speed engines, especially when the capacities of plants 1 and 3 are considered. While none of the figures represents the lowest cost which could be obtained if similar plants were installed to-day, it will be admitted that they are quite a good deal better than such plants are usually given credit for.

The total cost of the new power house at Gary, containing 10 units of 2,700 kw. each maximum continuous rating, when completed, will probably not be over \$70 per kilowatt, without the gas-cleaning plant. The latter would bring the cost of the whole station to a little over \$75 per kilowatt. Prominent

Under the favourable operating conditions at the Gary plant, the thermal efficiency of the gas-engine averages at least 21 per cent., particularly in view of the truly splendid physical condition in which this gas engine plant is kept. If the gas consumption of a gas engine or of a whole plant increases beyond the limit established by tests under similar load conditions, this must be due either to incorrect measuring methods or caused by "deferred maintenance," a term defined by Henry Floy as "the condition into which a power plant is permitted to lapse, due to neglect of proper maintenance and regular repairs."

Table III.—*Cost of Producing Electric Power at Gary. All Cost Figures in Cents per kw.-hr.*

	1910.	1911.	1912.
Capacity in kw.	40,000	40,000	50,000
Kilowatt-hour produced	116,535,000	157,742,510	286,575,000
Use factor, per cent.	33·3	45·0	64·5
Cost of Installation per kw.	\$88·00	\$88·00	\$88·00
Labour	0·0678	0·0421	0·0302
Repairs and maintenance	0·0366	0·0305	0·0273
Lubricants	0·0116	0·0100	0·0085
Water	0·0074	0·0057	0·0036
Miscellaneous	0·0064	0·0153	0·0128
Total net operating expense	0·1298	0·1036	0·0824
Value of gas	—	0·1508	0·1464
Cost of purification	—	0·0219	0·0144
Total cost of purified gas	0·1951	0·1727	0·1608
Operating cost without fixed charges	0·3249	0·2763	0·2432
Fixed charges at 15 per cent.	0·4520	0·3360	0·2310
Grand total at switchboard	0·7769	0·6123	0·4742

The operating expenses, without fuel cost or fixed charges, can be subdivided into the following items: Labour, repairs and maintenance, lubricants, water, and miscellaneous expenses. For the Gary plant, the cost of these various items for the last three years of operation is shown in Table III.

To give an approximate idea, however, of the relative cost of producing electric power in blastfurnace gas-engine and steam-turbine plants in this country, the costs and other interesting data obtained in eight steam-turbine stations and eight blastfurnace gas-engine plants were averaged, and the results are given in Table IV.

engines in these five plants in 1912 was 50·5 per cent. of that of the steam blowing engines.

The average saving of five gas blowing engine plants over five steam blowing engine installations was $2.52 per "blast unit" (1,606,140 cub. ft. of air at 15 lbs. pressure). The importance of this saving will be more appreciated when it is stated that the total actual cost of blowing the eight Gary blastfurnaces with gas blowing engines averaged—in 1912—only $3.26 per blast mile. Of this cost, 31 per cent. or $1.01 represents net operating expenses, and 69 per cent. or $2.25 the cost of purified gas. Illinois coal of 10,500 B.T.U. per

TABLE IV.—*Comparison of Cost of Producing Electric Power in Steam and Gas Power Plants. All Cost Figures in Cents per Kw.-Hr.*

		8 Steam Turbine Plants.					8 B.F. Gas Engine Plants.				
No. Item.	Item.	1 Maximum.		2 Average.		3 Minimum.	4 Maximum.		5 Average.		6 Minimum.
1	Plant capacity in kw.	126,000		55,000		10,000	50,000		11,600		1,500
2	Use factor, per cent.	33·3		25·0		10·0	71·5		49·0		22·0
3	Labour	·1730		·0902	58·1	·0134	·0881		·0550	33·0	·0302
4	Repairs and maintenance	·0740		·0422	27·3	·0250	·1282		·0733	44·0	·0273
5	Lubricants	·0096		·0054	3·5	·0020	·0237		·0125	7·5	·0054
6	Water	·0305		·0143	9·2	·0020	·0162		·0120	7·2	·0036
7	Miscellaneous	—		·0029	1·9		—		·0137	8·3	—
8	Total net op. expense	·2414	33·3%	·1550	100·0	·0850	·2438	52·2%	·1665	100·0	·0824
9	Cost of 1 million B.T.U. cents	11·10		8·80		5·20	10·37		8·11		5·89
10	Cost of fuel	·3960	66·7%	·3100		·1950	·2441	47·8%	·1530		·0963
11	Total cost of power production without fixed charges	—	100·0%	·4650			—	100·0%	·3195		—
12	Heat consumption per kw. hour B.T.U.	46,400		35,400		29,700	26,000		18,400		16,200
13	Thermal efficiency, per cent.	11·49		9·65		7·35	21·0		18·54		13·12
14	Ratio of plant capacities	1		1		1	·397		·212		·150
15	Ratio of use factors	1		1		1	2·130		1·960		2·20
16	Ratio of net op'g expenses	1		1		1	1·010		1·074		·970
17	Ratio of cost of 1 million B.T.U.	1		1		1	·934		·922		1·132
18	Ratio of fuel expense	1		1		1	·617		·493		·494
19	Ratio of actual fuel cost	1		1		1	·560		·536		·436
20	Ratio of total cost of production	1		1		1	—		·678		—
21	Ratio of heat consumption	1		1		1	·560		·520		·545
22	Ratio of thermal efficiency	1		1		1	1·830		1·923		1·785

The gas-engine installations in question belong to subsidiary companies of the United States Steel Corporation. Of the 10 blastfurnace gas-power plants in the Corporation, two were omitted, because one is of very small capacity and the other has not been in operation over two years. Three of the plants are located on the Great Lakes, four in the Pittsburgh District, and one in the Youngstown district. The figures are true averages covering three years' operation, 1910 to 1912.

Attention is called to the great difference in average capacity of the two classes of power plants, which should be noted when comparing the values in columns 2 and 5. It should further be borne in mind that electric light and power plants of public service corporations are organised and operated on a different basis than steel mill power stations. A steel mill power plant is only a means to an end—an auxiliary, as it were, in a vast system which is primarily concerned in the manufacture of steel and not in the production of power. Circumstances could hardly have been more unfavourable for obtaining fair average figures on blastfurnace gas-engine plants than those existing in the years 1910 and 1911, on account of the unsatisfactory condition of the iron and steel trade in this country. The average use factor for the eight gas-engine stations under discussion was 46·3 per cent. and 46·8 per cent. in 1910 and 1911, respectively. In 1912 it rose to 54 per cent., with the result that the cost figures for these plants were substantially improved.

Some very interesting information is available, which permits a comparison between reciprocating steam blowing engines and gas blowing engines in five blastfurnace plants in this country. While some of the steam blowing equipment is not new, it will nevertheless be surprising to learn that the average total cost of blowing blastfurnaces with gas blowing engines was 53·7 per cent., or a little more than one-half of that with steam blowing engines, all charges except fixed charges included. The average heat consumption of the gas blowing

pound would have to cost $0.42 per gross ton at Gary to reduce the saving, due to the installation of gas engines, to nothing, and to make a steam turbine installation commercially equivalent to the existing gas-engine installation.

In a number of steam-turbine plants of greatly varying capacity, in this country, the percentage of the total repair and maintenance cost per kilowatt-hour averages 27·5 per cent. of the total net operating expenses without fuel and fixed charges, as will be seen when referring to Table IV. The detail percentages for the eight steam-power plants, of capacities ranging from 10,000 kw. to 126,000 kw. with an average of 55,000 kw. maximum continuous rating, having use factors varying from 10 per cent. to 33·3 per cent., with an average of 25 per cent., are: 23, 11·5, 22, 23, 33, 40, 33, 32, 33·5, 31, and 32 per cent. The corresponding figures applying on eight American blastfurnace gas-engine plants, varying in capacity from 1,500 kw. to 50,000 kw. (average 11,600 kw.), and having used factors of 22 to 71·5 per cent. (average of 49 per cent.) were for three years' operation as follows:—

TABLE V.—*Repair and Maintenance Costs Expressed as a Percentage of Net Operating Expenses.*

Plant capacity kw.	1910 Per cent.	1911 Per cent.	1912 Per cent.
40,000-50,000	28·0	29·5	33·0
11,400	50·5	51·0	61·0
9,000	31·0	35·5	41·0
9,000	50·5	64·5	60·0
5,000	34·5	21·5	17·0
4,500	38·0	31·5	43·5
2,500	55·0	50·5	57·5
1,500	52·5	48·0	51·0
Average, 11,600	42·5	41·5	45·5
Average for three years' operation		43 per cent.	
Average use factor	46·3	46·8	53·9
Average for three years' operation		49·0 per cent.	

Comparison of these figures shows that the average percen-

tage of repairs for eight gas-engine installations is just 50 per cent. higher than the average percentage for eight steam-turbine plants. This is not surprising if the ratio of use factors (1 : 1·96) and of plant capacities (1 : 0·21) is considered. That some of these percentages are very high in several plants has a number of good reasons. The repair costs contain, for instance, replaced piston rods and defective gas cylinders, an expense which will largely be avoided in the future. At anyrate, these figures, especially those in Table V., show that gas engine repair costs are not "twice or three times as high as those of steam-turbine plants," as is frequently claimed.

The author made the statement some time ago that at least 12 per cent. of the power produced in gas engines is available from the waste heat to operate low-pressure steam turbines, and he is pleased to state that he found that at the Cockerill Works at Seraing a number of 1,500 h.p. blastfurnace gas electric engines are now equipped with waste heat boilers, designed by Mr. Leon Greiner, which actually produce sufficient steam day and night to generate in low-pressure steam turbines an amount of power equivalent to 13 per cent. of the original capacity of the gas engines.

The figures and facts presented were taken from actual records of blastfurnace gas-engine and steam-turbine installations in operation in this country. While the results obtained with gas engines are highly satisfactory and gratifying, and should reassure the iron and steel masters of this country concerning the economic advantages of the gas engine for their purposes, they are by no means the latest word in gas-engine practice. The new "scavenging and surcharging" system, which was recently devised and patented, and which is applicable on new as well as on existing 4-cycle gas engines, promises to fairly revolutionise future gas-engine methods. This system has been in successful use for nearly two years in a number of plants abroad, and its application has made possible an increase of the mean effective pressure and capacity of gas engines of given cylinder dimensions, of 25 per cent. and 35 per cent. above the original rating.

The increase in capacity results in a corresponding decrease in weight and cost per horse-power of the gas engine and the fixed charges of a power plant equipped with scavenged gas engines are thus materially reduced. Moreover, the net operating expenses are lowered while, incidentally, a better fuel economy is obtained. The reduction in first cost which affects not only the gas engines themselves, but also the items "buildings," "foundations," "electrical equipment," "piping," &c., will be over $8 per kilowatt, so that the first cost of a blastfurnace gas-engine plant will, in the future, not be a great deal higher than that of an equivalent steam-turbine plant, including boilers, condensers, and other auxiliary equipment essential for economical operation of the steam-power installation.

This scavenging and surcharging system, the utilisation of the heat now rejected in cooling water and exhaust, together with the improvements in design and construction which experience has taught, make the future of the large gas engine look brighter and more promising than ever.

In conclusion, I desire to extend to the officers of the United States Steel Corporation and its subsidiary companies, my sincere thanks for their liberal and broad-minded action in giving me permission to put before the institute the results and costs of operation of their gas-engine power plants. And I acknowledge with gratitude my indebtedness to C. J. Bacon, Chicago, for his assistance and co-operation in collecting and working up a very considerable part of the data.

Launch of a Torpedo Boat Destroyer.—H.M.S. "Sarpedon," a new torpedo boat destroyer, was successfully launched from the Wallsend shipyard of Swan, Hunter, & Wigham Richardson, Ltd., on the 6th inst. The vessel was ordered under the naval programme of 1912-13, and is similar to the "Shark," "Sparrowhawk," and "Spitfire," which were recently built by the same firm. The propelling machinery of the "Sarpedon" and the boilers have been built by the Wallsend Slipway and Engineering Company, Ltd. The engines consist of two sets of Parsons impulse and re-action turbines, each driving a propeller on a separate shaft. The water-tube boilers are of the Yarrow small tube type, and are fitted with oil burning apparatus.

EFFECT OF REMELTING GUN-METAL.

THE tin bronzes seem to be improved by remelting and the tensile strength increased. The same is true of aluminimum bronze, and it is impossible to make as good castings of the latter unless it is actually remelted (*i.e.*, melted twice). The following results on Government bronze (88 per cent. copper, 10 per cent. tin, and 2 per cent. zinc), given in a recent issue of the "Brass World," indicate that this remelting is advantageous, and also show how close the average brass foundry can be expected to work to a formula. The metal was cast in one of the smaller Eastern foundries in order to ascertain what could be done in the way of adhering to the formula and in the physical characteristics. The effect of remelting was also tried, and it will be noticed that the tensile strength and other physical characteristics are increased by this second melting. The variation from the formula intended is more than it should be, and it is possible to work closer than this. The fact that small melts were made and scales not sufficiently accurate were used is responsible to a large extent for the variation from the formula.

The results obtained were on a test bar of the following dimensions, and which was cast in green sand: Length, 13¼in.; diameter, 1¼in. The bar was turned down in the middle for a length of 10in. to practically 0·75 of an inch. The mixture made was: Copper, 88lbs.; tin, 10lbs.; spelter, 2lbs.

The following were the results obtained on the test bars cast in green sand:—

First Melt.

Diameter test bar	0·798in.
Broke at	14,400lbs.
Tensile strength	28,800lbs. sq. in.
Elongation in 8in.	10·2 per cent.
Reduction of area	10·6 "

Analysis of the Test Bar.

Copper	87·57 per cent.
Tin	10·54 "
Zinc	1·82 "
Lead	·04 "
Iron	·03 "

The following tests were made of the mixture that was twice melted. After it was first melted, it was poured into ingots, and these were then remelted and poured into the test bars. The melts were each different batches of metal.

Melted Twice.

Diameter test bar	0·798in.
Broke at	17,400lbs.
Tensile strength	34,800lbs. sq. in.
Elongation in 8in.	15·5 per cent.
Reduction of area	14·2 "

Analysis of Test Bar.

Copper	87·56 per cent.
Tin	10·57 "
Zinc	1·86 "
Lead	·04 "
Iron	·03 "

The following test bar was also made of metal twice melted, and the following results were obtained:—

Diameter test bar	0·798in.
Broke at	19,500lbs.
Tensile strength	39,000lbs. sq. in.
Elongation in 8in.	17 per cent.
Reduction of area	20·4 "

The appearance of the fractures of the bars indicated the character of the metal, as it always will on sand castings. The metal which had been melted only once showed a rather coarse, crystalline structure, which contained fine blowholes. The metal which had been melted twice showed no blowholes, and the structure of the fracture was finer grain and less crystalline than the other (that which had been melted only once).

The variation in the physical characteristics of the two test bars that had been melted twice is undoubtedly explained by the difference in the pouring temperature. It is now a well-

established fact that two test bars poured from the same mixture at different temperatures will have different physical properties. It will be noticed that the variations in the analyses of the three test bars were very slight, and they can, for testing purposes, be assumed identical.

INTERNATIONAL ENGINEERING CONGRESS, 1915.

IN connection with the Panama-Pacific International Exposition which will be held in San Francisco in 1915, there will be an International Engineering Congress, in which engineers throughout the world will be invited to participate. The congress is to be conducted under the auspices of the following five National Engineering Societies: American Society of Civil Engineers, American Institute of Mining Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, and the Society of Naval Architects and Marine Engineers. These societies, acting in co-operation, have appointed a permanent Committee of Management, consisting of the presidents and secretaries of each of these societies, and 18 members resident in San Francisco. The Committee has effected a permanent organisation, with Prof. Wm. F. Durand as chairman, and W. A. Cattell as secretary-treasurer, and has established executive offices in the Foxcroft Building, 68, Post Street, San Francisco. The 10 members of the Committee, consisting of the presidents and secretaries of the five national societies, will constitute a Committee on participation, through whom all invitations to participate in the congress will be issued to governments, engineering societies, and individuals. The personnel of this Committee is as follows: Chas. F. Rand (chairman), Chas. Warren Hunt (secretary), D. H. Cox, W. F. M. Goss, F. L. Hutchinson, Ralph Davenport Mershon, Calvin W. Rice, Bradley Stoughton, Geo. F. Swain, Robt. M. Thompson. The actual management of the congress and the work of securing and publishing papers will be in charge of the members of the Committee resident in San Francisco. The work of the resident members has been assigned to different subcommittees. The honorary officers of the congress will consist of a president and a number of vice-presidents selected from among the most distinguished engineers throughout the world. The papers presented at the congress will be divided into sections. During the congress each section will hold independent sessions, which will be presided over by a chairman eminent in the branches of engineering covered by his section. The scope of the congress has not as yet been definitely determined, but it is hoped to make it widely representative of the best engineering practice throughout the world, and it is intended that the papers, discussions, and proceedings shall constitute an adequate review of the progress made during the past decade and an authoritative presentation of the latest developments and most approved practices in the various branches of engineering work. The various committees are now actively at work, and it is hoped that further and more definite announcements as to the membership fees, schedules of papers, &c., can be made in the very near future.

The Institution of Gas Engineers.—The Jubilee meeting of the Institution of Gas Engineers will be held at Caxton Hall, Westminster, from June 17th to June 19th, under the presidency of Sir Corbet Woodall, D.Sc. After the president's address, the following communications are to be submitted: Report of the Refractory Materials Committee; "Coke Oven Carbonisation," by Mr. W. Chaney; "Liquid Purification," by Mr. W. B. Davidson; "Creating an Outdoor Staff," by Mr. F. W. Goodenough; "Depreciation—Estimated and Actual," by Dr. A. C. Humphreys; "Notes on Suburban Gas Supply," by Mr. A. A. Johnston; "Ventilation and Gas," by Mr. S. B. Langlands; "Gaseous Heating," by Mr. E. W. Smith and Mr. C. M. Walter. The Jubilee dinner is to be held at the Connaught Rooms on June 18th, and on Friday, June 20th, a garden party is to be given by the President and Lady Woodall at Chislehurst.

MECHANICAL OIL BURNERS.*

BY E. H. PEABODY.

THE "mechanical atomiser," so called, is understood to mean a device which sprays or atomises oil or other liquids by means of pressure alone, without the use of compressed air or steam or other exterior atomising agent. Owing to its simplicity and to the fact that no fresh water is wasted, it is being extensively used in the merchant marine, and it has possibilities which may ultimately bring about its adoption on shore.

Commodore Isherwood's conclusions of some 30 years ago hold good to-day, namely, that atomisation of the oil, as distinguished from vaporisation or gasification in the burner, is the only method that has been attended with success. There are not wanting those who still claim advantage for those forms of apparatus which, by various methods of treatment of the oil, admit the fuel to the furnace in the form of vapour. These systems, while successful in metallurgical work, have no standing in boiler practice for the reason that they show no gain in efficiency, but, on the contrary, result in very poor capacity, the latter feature alone making them undesirable for marine use.

The well-known Koerting process patent, taken out in this country in 1905, contains a claim which covers heating the liquid oil unmixed with air or other gases to a point above its

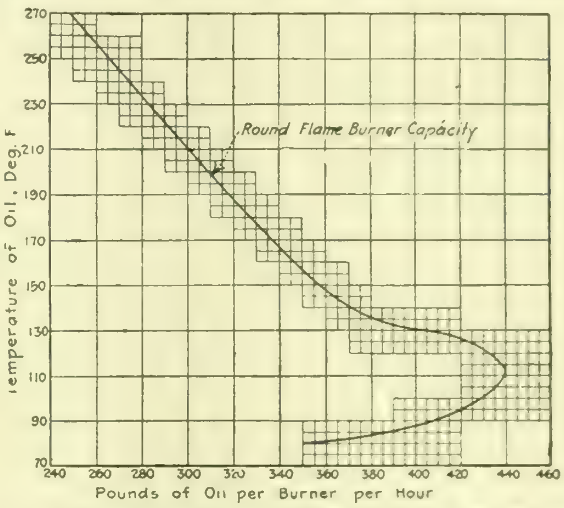


FIG. 1.—CURVE SHOWING VARIATION OF CAPACITY OF AN OIL BURNER, WITH CHANGE OF TEMPERATURE OF THE OIL HANDLED.

normal boiling-point, maintaining the oil in a liquid state by pressure and delivering the superheated oil into a combustion chamber supplied with air, whereby the rapid disintegration and vaporisation of oil in the presence of air are secured. The idea here, as is more fully pointed out in the patent specifications, is that the heat stored in the oil at high pressure will cause the liquid to flash into vapour when released at low pressure, exactly as water heated above 212° Fah. under pressure would flash into steam if released to the atmosphere. This is an exceedingly ingenious way of converting at least part of the oil into vapour without atomising it, but as a matter of fact no gain results from this partial gasifying of the oil. This question has been tested out experimentally and what is more to the point, nobody is doing it, not even the users of the Koerting apparatus itself. The dangerous expedient, therefore, of heating oil above its flash-point at atmospheric pressure is not found necessary.

The real value of heating the oil is rather a mechanical one, namely, to reduce the viscosity of the liquid so that it can be forced through the small passages of the burner and given a rapid whirling effect, sufficient in the more limpid condition of the oil to reduce it to a fine spray through the action of centrifugal force when liberated from the tip. It will be found from a study of fuel oils that, while the viscosity is tremendously affected by changes in temperature at the lower ranges, very little difference in viscosity results from heating or cooling as the temperatures approach the flash-point. With all ordinary oils it may be considered that heating to within 50° Fah. of the flash-point will be sufficient

* Abstract of a paper presented before the Society of Naval Architects and Marine Engineers, New York.

to render the oil suitable for use with the mechanical burner, and in the case of many of the lighter oils even this heating is unnecessary, the oil being sufficiently limpid at ordinary atmospheric temperatures.

Several methods of spraying oil by mechanical means have been suggested, such as forcing the liquid through a very fine aperture, forcing a jet of oil at high velocity against some object or against another oil jet, throwing the oil off from a rapidly revolving table or disc, or giving the liquid itself a whirling motion and reducing it to spray by centrifugal force. In 1902 the writer tried the first idea and succeeded in making a very poor flat-flame mechanical atomiser by forcing the oil

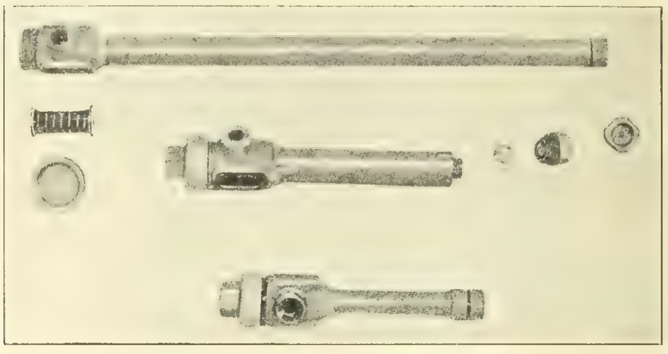


FIG. 2. PARTS OF PEABODY MECHANICAL ATOMISER FOR BURNING OIL FUEL.

between two flat surfaces pressed closely together, and in 1907, when in answer to the Navy's call we took up the matter of mechanical atomising seriously, we tried some of the other schemes. The experiment of making two round jets of oil strike each other on the principle of the acetylene burner, resulted very interestingly in flat spray — not fine enough, however, with heavy oils to be practicable. A mechanical atomiser, or, as it was called, a "self-atomiser," consisting of eight small jets meeting at a central point, was patented in England in 1904 by Charles Ferdinand de Kierskowski Steuart. It is a good example of spraying by forcing jets of oil to strike each other, but otherwise has attained no importance in the art.

The only method of atomising fuel oil mechanically which has attained any practical success is that wherein the oil is given a whirling motion inside the burner tip. There are two distinct means for doing this, first, by forcing the oil through a passage of helical form, like a screw thread, and second, by delivering the oil tangentially to a circular chamber from which there is a central outlet. Examples of the first form are shown in the spraying burners perfected by Schutte and by Howden and illustrations of the second form are given in those perfected by Jones and by Stringham and Elmendorf.

The matter of adjustability of an oil burner, that is, the ability to change the quantity of oil delivered in a given time without changing the oil pressure or the velocity of the liquid through the tip, while attractive in idea and perhaps well sustained in theory, has no particular value in practice. It is a fact that in regular operation on shipboard, the simpler forms of burners which do not possess this feature are quite as successful, if not more so than those possessing it. The manipulation of the oil pressure acting on all burners at once presents in itself a simple means for the control of output through a wide range. A good burner will atomise moderately heavy oil with an oil pressure as low as 30lbs. per square inch and from that up to 200lbs. or above. If this range is insufficient to meet the variable steam requirements, then it is easier and better to shut down a portion of the burners entirely than to attempt to adjust each individual burner separately, particularly as it is important to regulate the quantity of air admitted to the furnace for combustion, at the same time the quantity of oil is varied.

This air supply can be easily controlled for all burners by regulating the draught pressure, and the air can be closed off entirely when a burner is shut down. This puts the question of proper air supply more into the hands of the designer, requiring the operator to determine only the proper conditions of draught pressure for the plant as a whole, at the required capacity.

Another means of varying the quantity of oil delivered by all burners in addition to alteration of oil pressure is available in alteration of oil temperature. Generally speaking, under working conditions any increase in temperature of the oil results in decreased capacity of the burners, the pressure remaining the same. The reverse is the case at low temperatures, the critical point depending on the relationship between viscosity and specific volume of the oil in question.

This law is shown graphically in the diagram in Fig. 1, giving the results of a test on a sample of Texas oil of 18° gravity (degrees Baumé) and a flash-point of 240° Fah. The oil pressure was maintained constant throughout the test at 200lbs. per square inch and the temperature was raised by stages from 80° Fah. to the flash-point. The burner capacity increased rapidly up to a temperature of 110° where it reached a maximum. With continued heating it began to fall off and continued to do so throughout the range of the experiment.

It will be obvious, if oil is to be atomised by centrifugal force, that the best spray will be obtained by giving the oil the maximum whirling motion and reducing to a minimum the friction in the burner so that the whirling motion once obtained shall not be diminished before the oil is liberated. These are axiomatic principles, recognised by all, and no doubt each inventor believes he has best met the requirements. Probably these three questions are the controlling factors in the "survival of the fittest." (1) How heavy an oil will a burner thoroughly atomise? (2) What pressure and temperature are necessary? (3) What degree of simplicity has been attained in the design?

It may be said here that any apparatus which will not handle heavy oil will have a very limited usefulness. Already the market is beginning to be supplied with very heavy oils from Mexico, there is a considerable amount of crude oil in California below 15° gravity, and the tendency will be more and more to use the heavier residuums. Probably in a few years we will be using oils of 12° to 15° Baumé as commonly as we are consuming oil of 27° to 30° gravity to-day. There was recently received, for experimental purposes, some Mexican crude oil having the following characteristics: —

Specific gravity at 60° Fah.	0·981
Degrees Baumé at 60° Fah.	12·6
Moisture and silt	3·5 per cent.
Flash-point	310° Fah.
Burning point	347° Fah.
B.T.U. per pound (oil as received)	17,551

In appearance this oil was black and at temperatures of about 80° very sticky and viscous. On heating to 212° it turned to foam owing to the presence of so much water, and

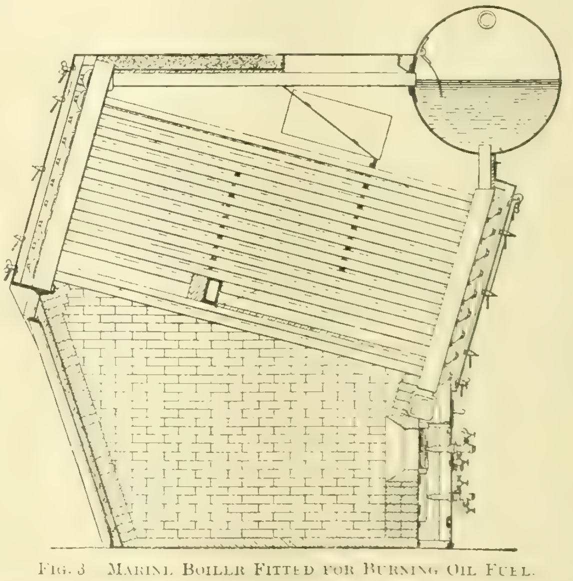


FIG. 3. MARINE BOILER FITTED FOR BURNING OIL FUEL.

this failed to separate out, a sample of the oil being thinned down with ether to determine the percentage. Ordinary settling tanks would have been practically useless, as the oil was so near the specific gravity of water. This oil was, however, successfully sprayed and burned under natural draught, on being heated to 270° at a pressure of 165lbs. per square inch. A slight amount of smoke was formed, which disappeared on a slight increase in the furnace draught above 0·12in. of water. The most noteworthy feature of the experiment was that the capacity fell off about 40 per cent. from that obtained with the same apparatus with oil of 18° gravity.

This sample of oil was the worst the writer has ever seen, but it is a specimen of what we may have to handle in the near future.

In the light of some experiments begun in 1907 we have come to believe that the best rotative effect on the oil is produced by the tangential delivery method, and it seems plain that the best way to reduce friction is to reduce the amount of surface to which the oil is exposed in its travel through the burner after it begins to whirl and until its exit from the tip. We have also come to attach great importance to simplicity in everything connected with oil burning and to believe that the oil burner itself should be of simple construction, easily taken apart, and so designed that when taken apart all the small passages and wearing surfaces will be exposed for inspection, cleaning, and repair.

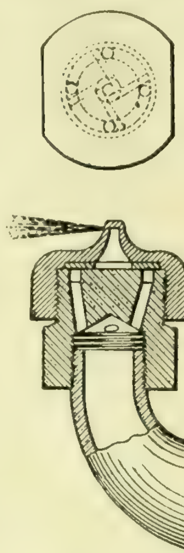


FIG. 4.—PROPOSED FORM OF FLAT SPRAY MECHANICAL ATOMISER FOR OIL FUEL.

The results of the writer's efforts to construct a burner to meet these requirements are shown in Fig. 2. Oil is delivered under pressure to an annular channel cut into the face of a nozzle upon which is screwed a tip having a very small central chamber communicating with a discharge orifice. Between the nozzle and the tip a thin washer or disc is inserted and held firmly in place. This has a hole in its centre corresponding with the diameter of the central chamber of the tip, and small slots or ducts extend tangentially from the edges of the central opening outward toward the periphery of the washer, long enough to overlap the annular channel of the nozzle and put it in communication with the central chamber. When this burner is assembled with the washer in place, oil is delivered through the ducts tangentially to the central chamber where it revolves rapidly and is almost immediately discharged through the orifice in the tip.

In order to correct a popular fallacy, attention should be called here to the fact that no mechanical atomiser produces a revolving spray, but the particles of oil fly off in straight lines under the influence of centrifugal force, thus forming a hollow, conical spray. The fineness of this spray, that is, the minuteness of the particles forming it, has a most important bearing on the results obtained in the furnace. It is possible with some forms of steam atomisers to atomise oil so finely that no flame at all will be produced, the incandescent combustion chamber being filled merely with a clear, invisible gas and every brick being discernible. It is doubtful if this condition of flameless combustion can be produced with mechanical atomisers and heavy oil, nor is it desirable under any circumstances for the simple reason that it costs too much.

With the production of flame, however, furnace design assumes an added importance, for the flame must be distributed evenly and without localising on the heating surfaces of the boiler, and the gases must be given time and space in which to expand and burn as nearly as possible to completion before being cooled and the flame extinguished by contact with the tubes of the boiler. These points become exceedingly vital when the boiler is forced to the requirements now demanded in naval service.

Having an atomiser, therefore, that will produce a fine spray with heavy oil and which is simple, reliable, and easily handled, the problem becomes one, not of oil burner, but of furnace design and air distribution. Our work has been carried on, until recently, entirely with the Babcock & Wilcox marine boiler, a design having a furnace ideally suited for any volatile fuel and particularly for oil. A longitudinal section through this boiler fitted with mechanical atomisers is shown in Fig. 3. It will be seen that the characteristics of this furnace are: Large volume in proportion to the heating surface of the boiler; upward slope of the roof toward the rear, resulting in increase in height and volume in the direction of the entering oil spray and thus providing room for the expansion and diffusion of the gases; small amount of boiler heating surface exposed, and, on the contrary, large exposed surface in incandescent refractory material, thus tending to maintain high furnace temperature and promote complete and rapid combustion of the oil; tubes almost parallel with the path of the oil spray injected into the furnace from the front, thus promoting proper distribution of the gases along the tubes and preventing local overheating; outlet from the furnace at the point most remote from the location of the atomisers, thus ensuring long travel of the gases; and, finally, means for bringing the heated products of combustion into the closest possible contact with the entire amount of heating surface of the boiler, discharging the waste gases into the uptake at temperatures but little above that of the steam generated. These conditions combined to relieve us of any worry about furnace design.

The experiments therefore developed principally into a search for the best method of admitting the air for combustion, in which process great delicacy is required. Very slight changes affect the results in unsuspected ways, and while almost any method may result in smokeless combustion, maximum economy and capacity can only be secured by careful and intelligent design. It is not necessary to give the air a whirling motion, but judging from our rather exhaustive experiments better gas analyses are secured, lower air pressures are required, and less refinement of adjustment is needed if the air is brought into contact with the oil spray with the right sort of twist.

Mention has already been made of the special advantages of flat spray atomisers, and the many forms of successful steam atomisers, which give a flat flame, warrant the belief that there is a wide field awaiting a thoroughly satisfactory flat spray mechanical atomiser. Reference has also been made in a previous paragraph to a flat flame atomiser, formed of two flat surfaces pressed together, and to another consisting of two round oil jets striking together. Neither of these schemes seems to promise very much in the way of material for development. Another form which does seem to possess some merit, however, is illustrated in Fig. 4. This consists of a means for giving the oil a rapid whirling motion as in the case of the round flame burner and then releasing the liquid through a slot in the side of the tip in a plane at right angles with the axis of revolution instead of through an orifice concentric with the axis. It is apparent that centrifugal force will here come into action as an atomising agent but that the spray will be flat instead of conical.

The only practical flat flame mechanical atomiser which has been put on the market is that brought out by the Schutte-Koerting Company, and installed by them on the U.S.S. "Utah." This burner is simplicity itself—a very considerable advantage—and the spray is excellent at low powers. About the only limitation which has been discovered in this burner is the fact that at anything over about 100lbs. of oil delivered per hour, the spray loses its finely diffused character.

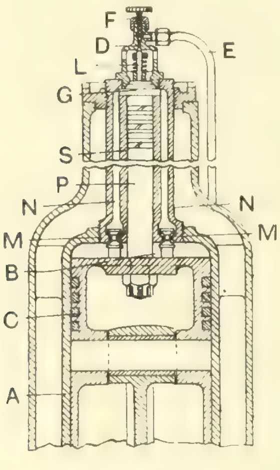
An effort has been made to show that while the problem of oil burning presents some difficulties, particularly as regards admission of air, there is very far from being any mystery about the matter. A strong leaning toward simplicity, "horse sense" and some experience, are a combination reasonably sure of giving good results, without depending very much on abstruse reasoning or higher mathematics. Improvements will be required and will be forthcoming, particularly in connection with spraying the heavier oils, and the flat spray atomiser has a promising field for development. Meanwhile the results already attained are certainly encouraging.

ROOTS OIL ENGINE.

A METHOD of feeding liquid fuel into internal-combustion engines is illustrated in the accompanying sectional view. The arrangement, which has recently been patented by Mr. James D. Roots, M.I.Mech.E., 58, Avonmore Road, West Kensington, London, W., is particularly applicable to engines in which the fuel is vaporised or partially vaporised in a pump by compressing air therein to a high pressure, and the mixture of fuel and air is injected through a mechanically actuated valve into a charge of compressed air in the engine cylinder, where it is ignited, either by the heat due to the compression of the air or by other means, such as an electric spark.

Referring to the illustration, which shows diagrammatically one cylinder of any usual two-stroke type arranged for

small high-speed engines, the working piston C is fitted with the small piston P centrally secured thereto. The small piston is provided with a sufficiency of packing rings at its upper end. On the down-stroke of the two pistons, the small piston P draws in air from the atmosphere through the valve L, and oil or liquid fuel through the orifice D, which is closed by a conical end on the valve stem fitting a seating. E is the oil pipe and F a screw-down regulating valve. The fuel and air are drawn in through the valve L until the small piston has completed its down-stroke. The return stroke compresses the fuel and air together to a pressure of, say, about 500lbs. per square inch. The mixture is compressed into the two small bored channels N, one on each side, which, together with the space G constitute the compression and clearance space. The ends of the passages N are provided with double-seated closing valves M. When the working piston approaches the dead point at the top of its stroke, and the air in the combustion chamber B has been compressed to, say, 270lbs. per square inch, the two valves M are lifted from their seats by the working piston, and the mixture is injected into the compressed air in the combustion chamber. The rise of pressure consequent on the explosion closes both valves on to the opposite seatings. When the pressure in the channels exceeds that in the working cylinder during the compression of the small piston, the valves change seatings again. The mixing, heating, vaporising, and injecting cycle of operations is repeated with every up and down-stroke of the plunger P.



ROOTS OIL ENGINE.

The air is compressed in the passages very rapidly. The heat of compression is retained, and the rising and falling of pressure in the passages sweeps the fuel and air owing to the surging of the air to and fro during suction and compression, over the heated surfaces of the passages. A larger volume of injecting air is thus delivered with the fuel than in Diesel engines when the injection valve or valves are mechanically opened. The air and fuel are mixed together, the fuel being vaporised, and when the injection valve is opened just prior to the dead point of the stroke, the relative volume delivered being larger than in Diesel engines, the result is that ignition and combustion take place more rapidly, an explosion rather than combustion. The compression pressure to effect regular ignition in the combustion chamber may, with some liquid fuels, for example, be before the valve is opened, only 250lbs. per square inch instead of 500lbs., as in Diesel engines, and the pressure in the valve passages about 450lbs. instead of 800lbs.

It will be observed that the small volume of air insufficient to combine chemically or ignite with the fuel is drawn together with the fuel through the valve, during the down-stroke of the plunger into highly heated passages forming the chief portion of the clearance space of the small cylinder, and is compressed rapidly with the fuel just prior to injection, the air not having time to cool, immediately prior to the delivery or injection of the mixture. The hydrocarbon is delivered, together with the air during the suction stroke of the small piston, into the small highly-heated passage, the air drawn in sweeping over the hydrocarbon during the suction stroke and again sweeping over it during the return or compression stroke of the piston, thus firstly during the suction subjecting the air and fuel to a mixing process, this mixing process being continued and nearly completed during the compression, which compression at the same time raises the mixture to a high temperature. The air is thus caused to surge to and fro over the heated hydrocarbon in small passages, a process of rapid movement that effects complete admixture and partial or complete vaporisation.

THE SLOW COMBUSTION OF COAL DUST AND ITS THERMAL VALUE.*

BY F. E. E. LAMPLOUGH, M.A., AND A. MURIEL HILL, B.SC.

THE investigations about to be described were undertaken, in connection with the experimental work of the Doncaster Coalowners' Committee, to elucidate to some extent the nature of the chemical changes involved in the slow combustion of coal dust, and to determine if possible the value of the heat changes accompanying the oxidation of different varieties of coal. Work was commenced in July, 1912, and attempts were first made to determine quantitatively the course of the oxidation which occurred in coal dust maintained at a temperature of 110° C. in electric heaters.

The evolution of heat was measured by carrying out the oxidation of the coal dust in a vacuum flask immersed in a water bath of regulated temperature. A sensitive thermo-electric method was used to record and measure continuously the temperature of the coal dust. The absorption of oxygen was determined by recording the fall in pressure continuously by specially devised apparatus. Analyses were made at the beginning and end of the experiment to correct for the carbon dioxide developed and for the evolution of methane, &c.

In the calculation of the oxygen absorbed by the coal, corrections were applied for the different specific gravities of the coal, for the change in temperature of the contents of the vacuum flask, for the accompanying change in the saturation pressure of the water vapour, for the change in the composition of the gas in the flask, and for the change in the barometric pressure. The heat evolution was calculated from the rise in temperature produced in the flask and its contents, and from the transference of heat from the flask to the water bath. For the former calculation, the specific heat of each coal was determined.

The rate at which heat was lost by the vacuum flask for a given difference of temperature between it and the water bath was measured by allowing the flask filled with water at a higher temperature to cool under conditions similar to those of an experiment with coal dust. The change in temperature was recorded as usual, and from the water equivalent of the flask, and the known amount of water it contained, was calculated the number of calories lost from the flask per hour for each degree of temperature difference between the flask and the bath.

The absorption of oxygen which occurred in the vacuum flask lowered the pressure of oxygen in the flask, bottle, and that part of the gauge in connection with the apparatus occupied by oxygen. The volume of oxygen absorbed was calculated in each case by the following formula:—

$$\frac{V + V' + V''}{76}\left(p - p' + 2l\right) + 0{\cdot}0823l\left(p - 5 - \frac{2l}{n}\right)$$
$$+ \frac{V \times 318\,(p - \pi)}{76\,(273 + t)}\,f - \frac{V \times 318\,(p' - \pi')}{76\,(273 + t')}\,f'\,;$$

where

V = volume of flask occupied by the gas, that is, 464 cubic centimetres, minus the volume occupied by the coal dust, which was calculated from its mass and specific gravity,

V' = volume of the bottle containing pure oxygen in connection with the flask,

V'' = volume of gas in the gauge and connecting tubes (with the mercury level in both arms of the gauge),

p and p' = the barometric pressure at the beginning and at the end of the experiment,

n = the number of times the oxygen was admitted into the apparatus by the automatic stop-cock,

l = fall in level of mercury in the open arm of the gauge ($2l$ = change in gas pressure),

t and t' = temperature of coal dust at the beginning and at the end of the experiment,

π and π' = saturation pressure of aqueous vapour at temperatures t and t',

f and f' = proportions of oxygen in the gas in the flask at the beginning and at the end of the experiment, and 318 = the temperature of 45° C. on the absolute scale.

In calculating the composition of the gas in the flask from which samples for analysis were taken in a vacuous sampling

* Paper presented at the annual meeting of the Institution of Mining Engineers, London, June 5th, 1913.

tube, a correction was applied for the degree of vacuum obtained, this having been determined by experiment. The sample was taken with the vacuum flask shut off from the bottle, in order to prevent any oxygen rushing in and mixing with the gas in the flask. An important further correction was required to allow for this removal of the sample from the flask and its immediate replacement by pure oxygen.

In the foregoing formula the first expression gives the absorption of oxygen represented by the fall in pressure of the gas in the flask, bottle, and gauge, assuming the temperature of the flask to be that of the bath, and that no rise in mercury in the closed arm of the gauge has taken place. The second expression corrects for the rise of level of mercury which actually occurs in the closed arm of the gauge previous to each admission of oxygen, a mean value for each rise in level being taken for the whole experiment.

In addition, a considerable change occurs in the amount of oxygen in the flask. This has to be corrected for by taking into account the change in the composition, temperature, saturation, pressure of aqueous vapour, and final pressure of the gas in the vacuum flask. The third expression gives the volume of oxygen in the flask at the beginning of the experiment, and the fourth expression the volume of oxygen at the end of the experiment. The difference between these two expressions is the loss of oxygen in the flask apart from the oxygen admitted during the experiment, which latter is contained in the first expression of the formula.

The coals experimented with were obtained from different localities. Some samples from the Bullhurst Seam were kindly sent by Mr. A. M. Henshaw, to whom the writers are greatly indebted for his interest during the earlier part of their work. Other samples of coal were supplied by the Doncaster Coalowners' Committee.

Table I. is a summary of the results of reliable experiments obtained with the final form of the apparatus. In no case does heating take place without absorption of oxygen, and, conversely, absorption of oxygen is always attended by heating of the coal. These two processes are obviously very intimately connected, and taking into account the very different qualities of coal examined, the numbers in the last column, which give the amounts of heat evolved during the absorption of 1 cubic centimetre of oxygen, are surprisingly concordant. The mean value obtained is 3·4 calories per cubic centimetre of dry oxygen measured at 0° C. When carbon is burnt to carbon monoxide and to carbon dioxide, the respective amounts of heat liberated are 2·6 and 4·4 calories during the consumption of 1 cubic centimetre of oxygen.

TABLE I.

(1)	(2)	(3)	(4)	(5)	(6)
Description of coal.	Ash.	Iron.	Oxygen absorbed at 0° cent.	Calories of heat evolved.	Calories evolved per cub. centimetre of oxygen absorbed.
	Per cent.	Per cent.	Cubic centimetres dry at N.T.P.		
Top softs, containing 43% of pyrites*	40	20·2	321	1,158	3·6
Anthracite	—	—	132	495	3·6
Top coal	1·1	0·1	459	1,275	2·8
Bullhurst	3·2	1·2	60	234	3·8
Hard coal No. 1	6·0	0·1	195	705	3·6
Top softs:—					
First part	2·8	0·8	534	1,684	3·2
Second part	—	—	1,041	3,089	3·0
Hard coal No. 2	4·0	0·1	1,110	3,196	2·9
Slack	3·2	1·4	31	115	3·7
Iron pyrites from coal*	—	—	240	800	3·3

* The word "pyrites" has been used throughout to designate the sulphide FeS_2 without prejudice as to its nature. From its crystalline form it was evident that some of the material used in the last experiment was pyrites and not marcasite.

All the samples, with the exception of anthracite, Bullhurst, and iron pyrites, were from the Barnsley Seam. In the case of "top softs" a sample of gas was taken during the progress of the experiment, and using the analysis of this sample, calculations were made of the thermal value of the absorption which occurred during two periods—the first six hours and the following 17 hours of the experiment. It will be seen that the values in the two parts of the experiment were nearly the same.

An experiment was made with a sample of pyrites occurring in coal. The material was collected from the coal thrown away during unloading in a large coalyard, and the sample was apparently free from carbonaceous matter. The thermal value of the total chemical changes taking place during the oxidation of pyrites proved to be very close to the value given for the oxidation of carbonaceous matter. Certain peculiarities of this experiment make the result rather less reliable than in the other cases.

Other interesting and important facts concerning the oxidation of coal were obtained during the experiments, and the data on these points are collected in Table II

TABLE II.

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Description of coal.	Oxygen absorbed.	Carbon dioxide evolved.	Carbon dioxide evolved per 100 cubic centimetres of oxygen absorbed	Initial rate of absorption per hour	Final rate of absorption per hour	Final temperature
	Cubic centimetres.	Cubic centimetres.	Cubic centimetres	Cubic centimetres.	Cubic centimetres	Degrees cent.
Top softs, containing 43 per cent. of pyrites	321	118	37	54	55	51·2
Anthracite	132	0	0	59	32	49·4
Top coal	459	5·4	1·8	46	46	52·7
Bullhurst	60	0·4	0·6	11·2	7·7	47·2
Hard coal No. 1	195	2·7	1·3	18·6	22·0	50·0
Top softs:—						
First part	534	3·6	0·7	186	—	—
Second part	1,041	20·8	2·0	—	189	66·4
Hard coal No. 2	1,110	12·1	1·0	90	78	62·5
Slack	31	0·02	0·06	14·0	13·7	46·6
Iron pyrites from coal	240	102	43	475	—	—

The third column of Table II. gives the volume of carbon dioxide developed during the oxidation, and for comparison with the oxygen absorbed at the same time the percentage ratio of these two quantities is given in column 4.

As the duration of the experiments varied from about four to 24 hours the initial and final rates of absorption of oxygen are given in columns 5 and 6 so that the speeds of the action for different coals can be readily compared. The partial pressure of oxygen at the beginning of the experiment varied, with an average value near 0·75 atmosphere, and to make these initial rates comparable, corrections have been applied to give the initial rates in pure oxygen, assuming that the rate of reaction is proportional to the partial pressure of oxygen, similar corrections being applied to obtain the final rates. The initial temperature was always near 45° C., and the final temperatures are given in column 7.

From the values for the amount of carbon dioxide evolved, it is at once seen that the oxidation of the coals containing little pyrites gives very little of this gas, whilst large volumes are produced in the two experiments with material rich in pyrites. The carbonaceous matter, which includes some of the higher cyclic unsaturated hydrocarbons, is probably oxidised chiefly by the addition of oxygen to the complex molecules. It is interesting to note that in the experiment conducted quantitatively in two parts, the production of carbon dioxide is much greater in the latter part of the experiment.

The large evolution of carbon dioxide was responsible for a curious phenomenon in the experiment with pyrites, a similar effect of much less degree being noticed in the experiment with "top softs rich in pyrites." The heat evolution when the pyrites was oxidised was at first very rapid, but quickly ceased, because, owing to the evolution of carbon dioxide, the further inflow of oxygen was largely prevented. The pressure of the gas at first fell considerably, but soon a minimum pressure was

reached, and this fall gave place to a rise, owing to the evolution of carbon dioxide, and finally atmospheric pressure was slightly exceeded. Oxidation, therefore, almost ceased because the oxygen in the flask was exhausted, and none could enter to continue the process. The taking of a sample at this stage admitted oxygen, which gave a fresh impulse to the reaction, and the temperature, which had become steady, again rose rapidly. Again the pressure curve showed a minimum pressure, owing to the evolution of carbon dioxide; and when a sample of gas was analysed the next morning, 15 hours later, it was found that the oxygen in contact with the pyrites had become reduced to 4·3 per cent.

The greater part of the carbon dioxide was evolved after most of the oxygen absorption had taken place. It may be concluded from this that the carbon dioxide is produced as a result of a reaction brought about by the products of the oxidation of the pyrites. The evolution of carbon dioxide is doubtless due to the action of sulphuric acid on limestone present in the pyrites. The sulphuric acid is formed by oxidation of the pyrites in the coal and by hydrolysis of the sulphates of iron produced at the same time. If this hydrolysis was complete, and there was no retention of carbon dioxide in the form of basic iron carbonates, the volume of the gas evolved should be equal to about 55 per cent. of the oxygen absorbed. The carbon dioxide evolved in the pyrites experiment was some 43 per cent. of the volume of the oxygen absorbed, but the rise in pressure caused errors which could not be properly estimated.

For the proper elucidation of the reactions occurring in the oxidation of pyrites, a modified method should be used, in which it is possible to remove and measure the carbon dioxide continuously, so that there should always be plenty of oxygen in contact with the material to continue the oxidation.

From the rates of absorption which are given in Table II., a valuable opinion may be formed of the relative extent to which these different varieties of coal would become heated when exposed in a finely-divided state to the oxygen of the air. The most rapid absorption of oxygen occurred in the case of pyrites picked from coal, and the figure is a minimum value, because the evolution of carbon dioxide would probably begin early in the action. Owing to the low specific heat of pyrites (0·12), as compared with an average value of about 0·3 for the other samples of coal, a given evolution of heat produces a much greater rise in temperature in pyrites than in coal. Thus for pyrites the initial rise in temperature was over five times, but the initial rate of absorption of oxygen was only two-and-a-half times as great as in the case of the experiment with "top softs."

It will be noticed that the rate of absorption of oxygen for top softs containing 43 per cent. of pyrites is only about a ninth as great as in the case of nearly pure pyrites. Possibly this is due to differences in the structure or physical form of the pyrites, but there may also be chemical differences to account for this.

In some experiments the proportion of oxygen in the flask became considerably diminished. Thus at the end of the pyrites experiment the gas contained only 4·3 per cent. of oxygen, whilst the proportions were 8 and 20 per cent. of oxygen respectively in the experiments with top softs and with top softs rich in pyrites. The corrected rates of absorption in the two last-named cases were slightly greater at the end than at the beginning of the experiment, but the temperature was of course higher. It seems certain from these facts that the oxidation and heating of coal dust could not be prevented by any moderate reduction in the proportion of oxygen present in mine air.

General Conclusions.—(1) The heat which was evolved when coal dust was heated in an atmosphere rich in oxygen was nearly proportional to the volume of oxygen absorbed, the mean value being 3·4 calories of heat produced during the oxidation brought about by the absorption of 1 cubic centimetre of oxygen.

(2) The production of heat may be attributed to two chemical changes, namely, the oxidation of iron pyrites and the oxidation of carbonaceous matter.

(3) The oxidation of carbonaceous matter in coals practically free from iron was not so rapid as in those containing much iron, but continued for a long time, comparatively little carbon dioxide being evolved, so that eventually there was considerable heat evolution even in the absence of ventilation.

(4) The oxidation of iron pyrites was at first very rapid, but soon almost ceased, because the flask became choked with carbon dioxide, which prevented further admission of oxygen. With conditions under which there is diffusion of air through the coal dust, and when a considerable amount of iron pyrites is present, the oxidation of this mineral would possibly be the predominant factor in the spontaneous heating of coal dust.

(5) Oxidation of coal dust takes place in contact with gas containing much less than the normal proportion of oxygen present in air.

(6) The oxidation of carbonaceous matter and the total changes occurring in pyrites during the absorption of a given volume of oxygen produce about the same amount of heat, so that the rate at which heat is given off in the oxidation of coal dust due to either process may with surprising nearness be determined by the volume of oxygen absorbed.

THEISEN'S CENTRIFUGAL APPARATUS FOR PURIFYING, COOLING, AND WASHING GASES.

THE accompanying illustrations show several designs of centrifugal apparatus for purifying, cooling, and washing gases, the invention of H. E. Theisen, 34, Elisabethstrasse, Munich. In the arrangement shown in Fig. 1, which is combined with a gas scrubber, both the gas and washing water pass radially through the disintegrator apparatus from the inside to the outside. The major part of the washing water is thus thrown against the inclined surface A and deposited in the channel at its periphery, and runs off at B. The gas, on the other hand, is centrifugalled further after the manner of known gas washing fans together with the remainder of the washing water into the spirally enlarged casing, the gas being carried off through a tangentially arranged outlet nozzle, whilst the remainder of the washing water runs off at C.

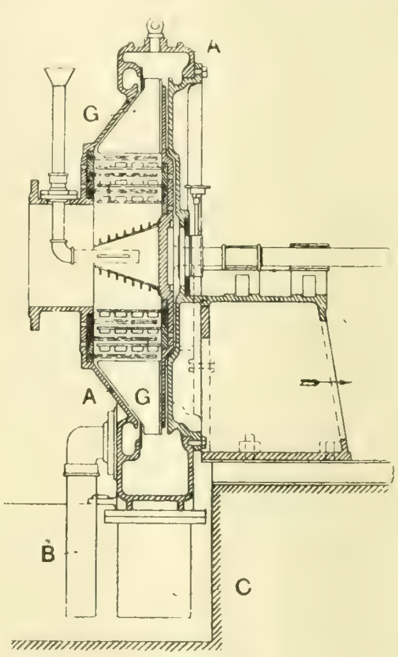


FIG. 1—THEISEN'S APPARATUS FOR COOLING AND WASHING GASES.

In the apparatus shown in Fig. 2 the gas enters at D into the annular chamber surrounding the disintegrator apparatus, and first comes in contact with the washing water in the lowermost part, which water is ejected here from the disintegrating apparatus, whereby it is first preliminarily cooled and purified. Under the action of the fan arranged on the right-hand side the gas is then drawn in the direction indicated by the arrows from all sides equally through the disintegrating device from the outside to the inside in counter-current to the washing water, which is thrown by the action of centrifugal force from the inside to the outside. The washing water itself escapes below at D, whilst the gas is further centrifugalled in the fan arranged at the right hand, together with the washing water carried with it, and, as described in connection with Fig. 1, escapes through a tangential outlet nozzle. The washing water, which in any case is separated in only small quantities, is carried off at any suitable place in the casing.

Fig. 3 illustrates another arrangement in which the gas enters at D. It is then drawn into the right-hand outer half of the disintegrator in the direction indicated by the arrows from the inside to the outside, *i.e.*, with the washing water, and then is conveyed again into the left-hand side of the disintegrator again from the outside to the inside, that is to

say, flows in an opposite direction to the washing water, and is then drawn off through the fan. In this arrangement a disintegrator which is to a certain extent double sided is provided, and the mixture and contact of the gas with the washing water is consequently thorough. The introduction of the washing water is effected by means of the pipe F. In

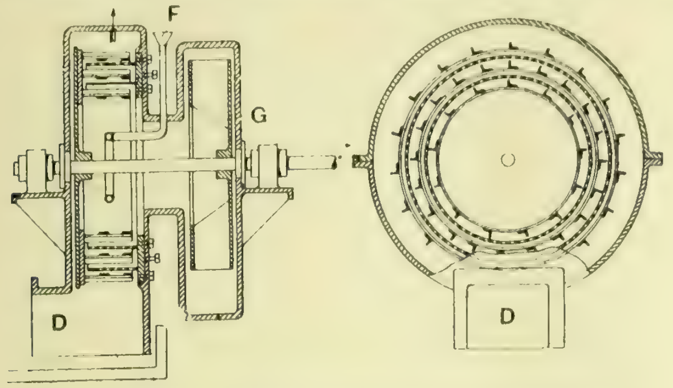


FIG. 2.—THEISEN'S APPARATUS FOR COOLING AND WASHING GASES.

this design also small quantities of washing water may be carried into the fan G, and therefore, even in this form of construction, the gas is again centrifugalled in the fan with

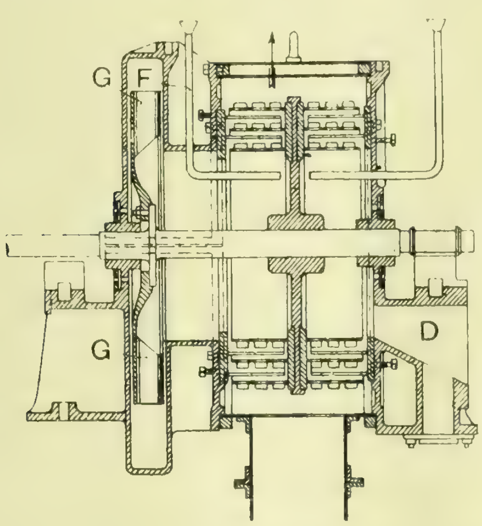


FIG. 3.—THEISEN'S APPARATUS FOR COOLING AND WASHING GASES.

the washing water. The gas is carried off through a tangential outlet nozzle, whilst the small quantities of washing water carried with the gas are discharged at any suitable place.

Self-contained Breathing Apparatus.—Mr. J. R. L. Allott, in a paper recently presented before the Institution of Mining and Metallurgy, described in detail the success of self-contained breathing apparatus worn by the Rescue Brigades when Norton Colliery (N. Staffs) was re-opened after the explosion in February of last year. He said that the first party wearing rescue apparatus descended slowly with mice, a canary, and safety and electric lamps, but without leaving the cage, they returned to the surface in half-an-hour. The mice and canary were not affected, but all the safety lamps were extinguished, it being estimated there was from 5 to 6 per cent. of fire-damp. The type of rescue apparatus used was the Proto Fleus-Davis pattern, and the lamps used were of the Oldham type. Further operations proved successful. The brigades worked with the apparatus for 120 days, although the actual time worked in the recovery of the dips was only 85 days, and they actually lived on their oxygen 360 hours during that period. This work at Norton, in an atmosphere which was absolutely irrespirable, constituted a remarkable record. He looked forward to the increased usefulness of self-contained breathing apparatus, and its application for purposes at present not contemplated. Dr. J. S. Haldane, who examined the rescuers at Norton, found no physical deterioration, except what a short holiday would repair.

STEEL CASTINGS AND THEIR SUBSTITUTES.

BY HENRY SOUTHER.

THE misapplication of the term "steel casting" is notorious. It is applied to so many widely different iron compounds that the layman, represented by the purchasing class, finds himself much at sea. It is difficult for him to comprehend the difference between real steel castings, semi-steel castings, malleable iron castings (often called steel), and a group of metals, bearing trade names and having a composition defying classification by metallurgists, that are sold as steel castings but which are far from it. The term "steel casting" should mean and does mean something definite. Such castings are made of the same kind of materials as the forged or rolled steel of commerce. Whether the steel be melted in a crucible, electric furnace, open-hearth furnace, or in a Bessemer converter of the standard type, or a modified Bessemer like the Tropenas or Thomas process, does not alter this fact.

Chemistry of Steel Castings.—The chemical composition of steel castings will be found to differ slightly, in accordance with the preference of the metallurgist in charge of the melting operations, or to suit the detail specification of the purchaser. All genuine steel castings are of the same nature as to composition and may be described in a general way as follows: The carbon (entirely in the combined form) may vary as desired—from 0·15 to 0·80 per cent., or even more. The manganese may vary in like manner, from 0·20 to 1·00 per cent. The silicon also is under control and may range from 0·05 to 0·50 per cent. The phosphorus and sulphur are impurities, and the amounts present in the final product are dependent to a large degree upon the selection of the melting stock and the melting process. A characteristic analysis of a steel casting suitable for general machinery purposes may be considered to be about as follows:—

	Per cent.
Carbon	0·30 to 0·40
Manganese	0·50 to 0·80
Phosphorus	0·06 to 0·08
Sulphur	0·06 to 0·08
Silicon	0·20 to 0·35

Higher carbons may be ordered for certain uses, and purer (*i.e.*, lower phosphorus and sulphur) material may be obtained if desired. Special alloy steels are also cast, as for railroad switch frogs, crossovers, and the like. All these steels are melted in a similar manner, are cast into moulds at the characteristic and very high temperature of genuine steel, are of a crystalline structure when cast and are substantially free from graphite or any form of carbon other than combined carbon. Such material may be annealed, heat treated, and refined the same as all carbon steel of commerce. They are cast steels just the same as is the ingot from which bar stock is subsequently rolled.

Semi steel.—This name is most misleading. It is applied to several metals (iron compounds), but mostly to one that is nothing more or less than ordinary grey cast iron to which a percentage of steel scrap has been added during the melting. The resulting metal has all the characteristics of grey iron. The amount of steel added (from 10 to 30 per cent. generally) is too small to alter materially the grey iron characteristics, and the material remains cast iron.

The whole process of steel making is devoted to the removal of carbon and silicon from iron, with the result that the product obtained contains but relatively small amounts of these elements and no carbon in the graphitic form. While steel is added to iron up to as high as 50 per cent., to produce the misnamed "semi-steel," even this large amount does not alter the character of the product; it retains all the characteristics of cast iron and has none of those peculiar to steel. The addition of steel to the iron mixture does modify the composition of the resulting cast iron, providing that the modification be not offset by a simultaneous change in the pig irons used. That is, the tendency of the steel to lower the silicon in the mixture is easily offset by the substitution of a higher silicon pig iron. This is also true to some slight extent with the total carbon.

Characteristic analyses of a genuine steel casting, grey iron

casting, and grey iron castings with different percentages of steel added are given below for comparison :—

	Steel, casting, per cent.	Grey iron, per cent.	Grey iron with 10 per cent. steel, per cent.	Grey iron with 40 per cent. steel, per cent.
Total carbon	0·35	3·50	3·25	2·50
Graphitic carbon	None	3·00	2·65	1·75
Combined carbon	0·35	0·50	0·60	0·75
Manganese	0·50	0·50	0·50	0·50
Phosphorus	0·06	0·75	0·70	0·60
Sulphur	0·06	0·10	0·10	0·10
Silicon	0·20	2·50	2·25	1·50

The marked differences between a steel casting and semi-steel or grey iron as to composition are noticed in the amounts of total carbon, graphitic carbon, phosphorus, and silicon. Any of the cast irons given above may be obtained by a proper selection and mixing of pig irons. Consequently, there is no warrant for the name "semi-steel." Such metal is not steel in any sense of the word; it is grey cast iron.

Malleable Iron Castings.—This is a proper term and one of long standing. It means what it says—a cast iron in a malleable condition. Malleable iron castings are often improperly called and sold as steel castings. Often steel castings are ordered and needed, and malleable iron furnished. More than one lawsuit has been based on such a cause.

Malleable iron as cast is a hard, white iron, and is rendered malleable by prolonged annealing treatment. This white cast iron that is annealed in order to produce malleable iron is the same as found in chilled car wheels, chilled rolls, and other chilled iron castings; and no other iron will do as well for the purpose. That the product is not steel will be readily observed from the following comparative analyses:—

	Malleable iron. casting.	Genuine steel. casting.
Total carbon	2·80	0·30
Graphitic carbon	2·70	None.
Combined carbon	0·10	0·30
Manganese	0·50	0·50
Phosphorus	0·20	0·06
Sulphur	0·06	0·06
Silicon	0·75	0·20

The differences here, as with the grey iron and so-called "semi-steel," are in the total carbon, graphitic carbon and silicon contents.

Pseudo Steel Castings.—Other castings masquerading under the name of "steel castings" are found in trade and partake more or less of the nature of grey iron and malleable iron. They are made by mixing special pig irons, steel, ferro-silicon compounds, and other special alloys. The physical characteristics of the resulting iron castings are modified to some extent by special methods of casting and cooling, and by annealing and partial annealing. The following analyses are from castings which are offered for sale as steel and are examples of the misrepresentation often practised. All contain graphitic carbon in considerable percentages.

	Carbon						
Sample.	Total.	combined.	graph.	Mn.	Phos.	Sul.	Sil.
A	1·50	0·05	1·45	0·21	0·166	0·052	0·65
B	2·14	0·27	1·87	0·38	0·158	0·052	0·74
C	2·72	0·52	2·20	0·25	0·166	0·069	0·61
D	1·31	0·83	1·48	0·05	0·061	0·092	0·72
E	1·11	0·96	0·15	0·13	0·060	0·102	0·64

	Carbon						
Sample.	Total.	combined.	graph.	Mn.	Phos.	Sul.	Sil.
F	2·19	0·65	1·54	0·02	0·045	0·540	0·57
G	2·91	0·69	2·22	0·16	0·044	0·228	0·60
H	1·27	0·56	0·71	0·36	0·192	0·065	1·01
I	1·13	0·36	0·77	0·08	0·052	0·102	0·59
J	1·51	0·45	1·06	0·13	0·082	0·085	0·49

Physical Qualities.—Genuine steel may be made of any desired composition in order to obtain great strength, great toughness and powers of endurance under severe loads. In other words, the carbon content may be increased, alloys may be added, and heat treatment may be resorted to so as to produce steel castings of very high elastic limit combined with considerable toughness as indicated by elongation and reduction of area. Elastic limits as high as 50,000lbs. and 60,000lbs. per square inch are easily obtainable, and coupled with such strength an elongation of 20 per cent. in 2in. and a reduction of area of 40 per cent., are possible. These figures are not extreme.

In contrast with this, the other iron alloys passing under the name of steel castings are not under any such control and at the best are relatively weak and brittle. Such castings cannot be depended upon to show more than 40,000lbs. to 50,000lbs. per square inch tensile strength, with a very indefinite elastic limit and in many instances none at all. This, coupled with the fact that the reduction of area and elongation are invariably low, limits the use of such materials very decidedly. These materials are not in the same class with steel castings and should not be substituted for steel without careful investigation and consideration.

Conclusion.—Manufacturers and purchasing agents must guard against the practice of substituting these misnamed metals for genuine steel castings by learning what kind of metal they can use to advantage and purchasing under specifications drawn to cover such material in a clear and practical manner. Some of these misnamed irons may be just the right thing for certain purposes and most desirable. But the use of the word "steel" is not at all likely to enable one to obtain the same metal twice in succession under the present practice. Such practice is dangerous and costly. It may, however, be improved by the use of the same amount of care in the purchase of steel and iron castings as is used in connection with the purchase of other commodities, as, for example, babbitt metal. Not all castings called steel should be accepted as genuine any more than all babbitts are accepted as genuine. Some babbitts are 50 per cent. lead, at 6 c. per pound, and some 90 per cent. tin, at 50 c. per pound. Purchasers have known this for many years and have guarded against being misled by a trade name. Knowledge as to steel castings is not as widespread, and it is for this reason that this article is published. Buyers should not accept all castings called "steel" as such. Take precautions to buy the kind of a casting intended and really needed, and accept no casting as steel which contains graphitic carbon.—"The Iron Age."

INDUSTRIAL AND TRADE NOTES.

Egyptian Petroleum Production.—The first exportation of Egyptian crude petroleum from the mining areas in the Red Sea took place last year, the total amount being 14,400 tons. When the refineries at present under construction at Suez have been completed, the crude petroleum will probably be brought to that port for refinement, instead of being exported direct to the Far Eastern refineries, as at present.

Shipbuilding Conference at Edinburgh.—A conference between shipbuilding employers and representatives of trades signatory to the National Shipyard Agreement met in Edinburgh on the 4th inst. Though no communication was made at the adjournment as to the course of the discussion, it is understood the possibility of some compromise being reached was still entertained. The result of the ballot was as follows: For a strike, 12,215; for accepting the employers' proposals for an adjournment of the question for three months, 4,348. The conference was resumed on Wednesday last, but owing to our having to go to press early on that day we cannot give the result.

Contracts for Electrical Machinery.—The Newport (Mon.) Town Council have approved the acceptance of the tenders of the A.E.G. (Electric Company) for a 3,000 kw. turbo generator and a 3,000 kw. condenser at £7,120, and of the Lancashire Dynamo Company for a 600 kw. direct-current generator at £935. It was stated by the chairman of the Electricity and Tramway Committee that the committee had no option but to ask the Council to go outside the country. There were 36 tenders for the plant, and no English firm came anywhere near the price quoted by the German firm, which meant a saving of £1,326.—A contract for the electrical equipment of over 40 trains for the electric section of the London and North-western Railway has been arranged with the Oerlikon Machine Works at Oerlikon, near Zurich.

A Large Turbo-generator.—The General Electric Company have secured a contract for the construction of what will be the largest electrical generator in the world. The unit, which is to be installed in the North-west generating station of the Commonwealth Edison Company, Chicago, will be a 30,000 kw. horizontal turbo-generator, and will be delivered about July 1st, 1914. The exciter will be installed on the shaft of the machine, which will have an overall length of 60ft. 6in. The width will be 18ft. 1in., and the height 14ft. The generating end of the unit will be a 9,000-volt, 25 cycle, 3 phase, bipolar machine with an output of 1,925 amperes per phase and a speed of 1,500 revs. per minute. The turbine will be operated by steam at 230lbs., superheated 200° Fah. The weight of the entire unit will be about 150 tons.

Launch of an Oil-tank Steamer.—The "San Gregario," an oil-tank steamer of 15,700 tons deadweight capacity, was launched on the 6th inst. from the Wallsend shipyard of Swan, Hunter, & Wigham Richardson. The vessel, which is built on the Isherwood system and is fitted with quadruple expansion engines and boilers designed to use Mexican oil fuel, is the third which has been launched for the same owners within the past three weeks, and the sixth of the fleet of 19 ships intended for the distribution of the Mexican oil fuel and other petroleum products of the Mexican Eagle Oil Company. The sister ship "San Fraterno" has just returned from Mexico with a full cargo, having made the round trip at an average speed exceeding 11 knots on a consumption of only 38 tons of Mexican oil fuel per day, three only of the four oil fired boilers being employed. The outward voyage was completed two days earlier than was anticipated, and the homeward trip one day.

Trade of the United Kingdom.—The first volume of the annual statement of the trade of the United Kingdom with foreign countries and British possessions for 1912, and a comparison of the four preceding years, has just been issued. The gross total value of imports of merchandise consigned from foreign countries in 1912 was £558,627,257, compared with £508,897,796 in the preceding year. The gross total value of imports from British possessions (including protectorates) was £186,013,374, compared with £171,259,731 in 1911. Together the value under both heads was thus £744,640,631, compared with £680,157,527 in the preceding year. The exports of produce and manufactures of the United Kingdom to foreign countries amounted to a total value of £310,130,801, compared with £295,275,154 in 1911. The total value of the exports to British possessions (including protectorates) was £487,223,439, as compared with a total of £454,119,298 in 1911.

Electrical Enterprises in Corea.—According to a report by H.M. Consul-General at Seoul, the total amount of capital invested in electrical concerns in Corea is about £1,225,000. Of this sum £980,000 is invested in concerns already working, and the balance in electrical works which are in course of construction. During the year two new companies commenced operations. One supplies the town of Gensan with light and power, and is the only hydro electric company in the country; the other supplies light and power to the town of Taikyu. Eight more companies which have already received official sanction are expected to commence work during 1913. For the moment there would seem to be a general tendency to await the results of the undertakings now in hand before embarking upon new enterprises. Though British electrical machinery is perhaps not as largely represented in Corea as could be desired, nevertheless a considerable portion, especially prime movers and boilers, is of United Kingdom manufacture.

Belgian Coal Production.—The total production of coal in Belgium during 1912 amounted to 22,983,460 tons, as compared with 23,125,140 tons in 1911, and 23,927,230 tons in 1910. This decrease was due to the strike in the Borinage district at the beginning of the year, and also to the limiting of the day's work to nine hours. Although this decline in production may appear discouraging, it is in reality not unsatisfactory, for in spite of the further reduction of the working day from 9½ hours in 1911 to nine hours in 1912, there was a decrease of only 141,680 tons, while the production of 1911 was 800,000 tons less than that of 1910. If the strike in the Borinage, which lasted over a month, had not taken place, causing a reduction of 500,000 tons in the output, the total output for 1912 would have been considerably greater than in 1911. The conclusion drawn from this in Belgium is that the limiting of the working day has not had the disastrous results anticipated. The owners of the coal mines proceeded to improve their machinery, tools, &c., and the results for 1912 go to show that the increased effective power of the engineers offsets the reduced work of the miners.

New Ironworks in Sweden.—The British Vice-Consul at Nykoping reports that a powerful syndicate is planning the erection of large iron works, electricity works, and coke ovens in Oxelosund, which may be considered as an exterior port of Nykoping. These iron works are to be on a large scale and capable of an annual output of about 80,000 tons of foundry pig iron, which corresponds to the present entire import of this article into Sweden. The new iron works will also be exceedingly well situated for exportation to the countries round the Baltic, particularly Finland and Russia. The company is said to have made a contract on very favourable terms for the supply of iron ore from the mines at Grangesberg. It will make coke to meet its own requirements, and will, in addition, be able to sell about 40,000 tons of coke every year. The present importation of coke into Sweden amounts to 325,000 metric tons, out of which about 225,000 tons are required for furnace and foundry purposes, the former coming chiefly from the United Kingdom and the latter from Westphalia. All by-products will be utilised. The electric power plant will be of large capacity. The capital necessary for all these undertakings amounts to between £400,000 and £450,000, and has already been fully guaranteed. The British Vice-Consul adds that Oxelosund is open all the year round; it has no harbour dues, and, with its excellent communications by land and water in all directions, is sure to gain in importance.

Trade Circulars and Catalogues.—Messrs. D. Bridge & Co., Castleton, send us a new catalogue of friction clutches and apparatus in connection with mill gearing and haulage, illustrated with photo views of actual installations they have erected.—The Schniewind Electric Company send us an illustrated circular and price list of various types of electric heaters.—David Brown and Sons, Ltd., Huddersfield, send us an illustrated pamphlet referring to the mounting and cutting of double helical gears.—Messrs. Sleeper Hartley, of Worcester, Mass., U.S.A., send us a series of leaflets describing types of machines they construct for coiling wire into various kinds of springs.—The Mirrlees Watson Company, Ltd., Glasgow, send us a pamphlet describing a surface condensing installation supplied by them to the Glasgow Corporation Tramways, for the Pinkston electric power station, and fitted with the "Mirrlees-Leblanc" rotary air pump. The results obtained with the new plant, both as regards the vacuum and the mechanical running, have, it is stated, been extremely satisfactory, and the type is particularly recommended when working with steam turbines requiring a high vacuum.—From Hans Renold, Ltd., Manchester, we have received a pamphlet, entitled "Driving Chains for Speeding Up," the contents of which show some remarkable results in lowering "production costs" as a direct result of using chains.—F. J. Down, of 6, Crutched Friars, London, E.C., sends us a circular relating to a type of spring percussion hammer for drilling holes in concrete, stone, brickwork, &c. The percussion effect is secured by turning a handle and ratchet wheel with its axis at right angles to a tube carrying the spindle and spring, which is alternately compressed and liberated by the action of the ratchet. The idea is rather novel, and the tool appears to be a very convenient one for plumbers, electricians, and gas and water fitters, who have frequently to drill small holes in walls and foundations.

METAL QUOTATIONS.

TUESDAY, JUNE 10TH.

Aluminium ingot	95/- per cwt.
„ wire, according to sizes, &c. ......from	112/- „
„ sheets „ „ ...... „	126/- „
Antimony	£31/10/- to £32/10/- per ton.
Brass, rolled	8½d. per lb.
„ tubes (brazed)	10⅝d. „
„ „ (solid drawn)	9½d. „
„ „ wire	8⅜d. „
Copper, Standard	£65/7/6 per ton.
Iron, Cleveland	55/10½ „
„ Scotch	61/10½ „
Lead, English	£20/10/- „
„ Foreign (soft)	£20/5/- „
Mica (in original cases), small	6d. to 3/- per lb.
„ „ „ medium	3/6 to 6/- „
„ „ „ large	7/6 to 11/- „
Quicksilver	£7/10/- per bottle.
Silver	27½d. per oz.
Spelter	£25/15/- per ton.
Tin, block	£206/5/- „
Tin plates	14/- „
Zinc sheets (Silesian)	£26/15/- „
„ (Stettin; Vieille Montagne)	£26/17/6 „

An International Fire Library.—The British Fire Prevention Committee having established a technical library that will be known as the International Fire Library, with a nucleus of over 2,000 books dealing specifically with matters of fire prevention, fire service and fire loss, is desirous of calling the attention of authors, public authorities, publishers and collectors to the fact that a new catalogue is in preparation, and that any books, pamphlets, or reports which they are able to spare for this collection should be addressed, as soon as possible, to the Honorary Chief Librarian, The International Fire Library, 8, Waterloo Place, Pall Mall, S.W.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Burners for liquid fuel. Kermode. 4093.
Aeroplanes. Schmiede. 1336.
Valves and valve gear for fluid pressure engines and pumps. Vane. 8180.
Gyroscopic apparatus. Gray & Burnside. 9246.
Construction of iron, steel, or metal ships. Long & Long. 10119.
Surface feed-water heaters. Morison. 11136.
Ships. McVittie. 11669.
Manufacture of fuel. Butler. 11680.
Steam traps. Paterson. 11697.
Metal-working machines. Veignault. 11707.
Ships or vessels. Stevenson. 11768.
Armour-plates. Fischer. 11784.
Gas compressors. Edwards & Balfour. 12192.
Gearing for the transmission of power. Paccagnini & Carbone. 12226.
Rotary gas engines. Trebert. 12336.
Mining machines. Van Slyke. 12364.
Process for obtaining gas from peat, oil, sawdust, or like material. Oligny. 12562 and 12563.
Internal-combustion engines. Forster & Kacafirek. 12777.
Carburetters for internal-combustion engines. Player. 12799.
Obtainment of dry air for use in blastfurnaces. Johnson. 13050.
Air intake fittings of carburetters for internal combustion engines. Charles H. Pugh, Ltd., and Starkey. 13064.
Navigable vessels. Macnab. 13114.
Screw propellers. Le Dantec. 13140.
Heat insulating materials. Sokal. 13248.
Valve-operating mechanism. Vickers, Ltd., and McKechnie. 13585.
Apparatus for scraping and cleaning boiler tubes. Walker. 13699.
Steam generators. Brown. 14435.
Methods of mining coal, converting it into gas, and then conveying the gas from the mine. Hoadley. 14494.
Production of metal castings. Thomas Holcroft & Sons, Ltd., and Holcroft. 15286.
Means for preventing the heating of bearings. Aktiebolaget Ljungstroms Angturbin. 15377.
Valves of the main pumping plants of floating docks and pontoons. Taylor. 15691.
Steam superheaters for locomotive boilers. Stirling. 16686.
Brakes for railway wagons. Locker. 16755.
Automatically working hydraulic draught and combustion regulating devices. Broux. 16947.
Apparatus for the adjustment of the gauge of rails on railways. Williams. 17193.
Fuel supply systems for explosion engines. Bassford. 17659.
Feed mechanism for machine tools. H. W. Ward & Co., and Deakin. 18875.
Safety devices for indicating deficiency of lubricating oil in engines. Rosentreter. 18999.
Aeroplanes. Laycock. 19502.
Means for operating tramway points. Coulombe. 19517.
Vacuum casting machines. Wright. 19552.
Furnaces of the tunnel or channel type. Marks. 19607.
Internal-combustion engines. Lafontaine & Lafontaine. 19677.
Shipbuilding slips. Evans. 19781.
Differential gears. Morris. 19850.
Siliceous material applicable as a heat insulator. British Thomson-Houston Company. 19927.
Carburetters for internal-combustion engines. De Veulle. 20237.
Composition for treating belting. Vacheron. 20553.
Hydrocarbon nozzles of spray carburetters. Cremieu-Javal. 21108.
High speed drills. Campbell. 21155.
Means for withdrawing water from the casings of steam turbines. G. & J. Weir, Ltd., and Petermöller. 21330.
Valve mechanism of internal-combustion engines. Perrot, and Argylls, Ltd. 21701.
Ventilating mines and conveying mined material to the surface. Hartmann. 21979.
Distribution of air for pneumatic hammers. Van de Poel. 21980.
Puddling furnaces. Millard & Hadlington. 22073.
Governing mechanism for elastic fluid turbines. Warwick Machinery Company (1908). 22665.
Apparatus for testing piston rings. Campbell. 23182.
Packing for pistons and piston valves. Suburn. 23535.
Airships. Andersson. 24199.
Transmission gear for motor vehicles. John I. Thornycroft & Co., and Niblett. 24226.
Worm and like milling machines. Brown & Bostock. 25406.
Gas starters for internal-combustion engines. McCarthy & Booth. 26568.
Apparatus and appliances for filtering and separating lubricating oils. Lister. 27353.
Expansion joints for pipes. Badger. 27717.
Smoke conductors for locomotives. Wheeler. 28034.
Driving belts for machinery. Booth. 28764.
Steam generator furnaces. Nordstrom. 29154.
Uni flow steam engines. Davidson. 29802.
Hacksaws. Ciarkowski. 30095.

1913.

Automatic couplings for railway vehicles. Paynter. 1080.
Piston rings. Ferber. 1094.
Open hearth suction gas producers. Crossley & Fielden. 1121.
Rotary slide valves for internal-combustion engines. Lentz. 2222.
Aeroplanes. Austin. 3214.
Hydraulic power transformer. Heindl. 3693.
Devices for automatically adjusting the time of ignition in internal combustion engines. Robert Bosch. 4693.
Controlling tapped turbines. Bergmann Elektricitats Werke Akt.-Ges. 7758.
Furnace grates. Grabowsky. 8743.
Devices for refacing valves and valve seats. Noé. 8979.

ELECTRICAL, 1911.

Dynamos. Lecoche. 28766.

1912.

Automatic telephonic apparatus. Degenhardt. 3978.
Telephony. Brown. 4067.
Wireless telephony. Ditcham, Matthews, & Grindell Matthews Wireless Telephone Syndicate, Ltd. 6486.
Distribution of electric energy. Waters. 11559.
Electric current distribution system. Bloustein. 11584.
Methods of equalising the load on systems of supply for direct-current electric motors. Eckmann. 11597.
Wireless telegraphy or telephony. Merton. 11714.
Devices for damping the oscillations set up in alternating current dynamos. Siemens-Schuckertwerke Ges. 11957.
Electric heating device. Martin. 12075.
Electrical resistances. Soar. 13213.
Apparatus for starting an internal-combustion engine by means of electric energy. Hartford & Mastrangel. 14929.
Electromagnetically operated switches and cut-outs. Siemens Bros. Dynamo Works, Ltd., and Brooks. 15659.
Ironclad electric switch and distribution boards. Berry & Markham. 18349.
Generator regulators. Lake. 18425.
Electric flame arc-lamps. Angold. 18908.
Electric switches. Page. 18980.
Contact fingers or brushes for electric controllers. Cox. 19740.
Electric indicating apparatus. Tyler Apparatus Company, and Bishop. 21179.
Electrical regulating apparatus. Soc. Ed. Gabreau, and P. Delaux. 21813.
Indicators for electric switches. Berry. 22539.
Electromagnetic ore separators. Rietkötter & Claes. 24135.

1913.

Connecting terminal for high-voltage circuits. Haefely. 119.
Combined mechanical locks and electric circuit breakers for lift doors and gates. Electromotor Equipment Company, and Brenner. 1433.
Windings of alternating-current dynamos. Allmanna Svenska Elektriska Aktiebolaget. 7776.

The Institution of Municipal and County Engineers.—The Institution of Municipal and County Engineers has decided to hold a conference at Great Yarmouth on July 16th and 17th next, with delegates from the various corporations and local authorities of the kingdom, represented in the membership of the institution, on the subject of the carrying out of the provisions of the Housing and Town Planning Act, 1909. The conference will open on Wednesday afternoon, July 16th, when the president will deliver his address and present the premiums of the Institution. In the afternoon there will be a conference on the Housing and Town Planning Act. On the Thursday morning papers on road matters will first be discussed and then the conference on the Housing and Town Planning Act will be continued. In the afternoon there will be further papers on road matters, and then the conference continued and concluded. The annual dinner will take place in the evening. On the Friday morning there will be papers on road matters and subjects of general interest.

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WILLIAM H. FOWLER
Wh. Sc., M.Inst.C.E.
Telegrams: "Scientific," Manchester.
Telephone No. 8638. Central.

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The Choice of a Prime Mover.

THOSE members of the profession concerned more particularly with the problems relating to the use and production of power must feel at times a little difficulty in maintaining familiarity with the varied aspects of latter-day developments, and even more so in keeping free from prejudice when called upon to weigh their relative pros and cons. Time was when many of us, who would not yet like to be regarded as old, had only the varied types of reciprocating steam engines to consider when questions of power were involved. It is true discussions often waxed hot round such points as the respective merits of high pressure or low pressure, horizontal or vertical, compound or single cylinder, condensing or non-condensing, and a glance at some of these old disputes furnishes amusing reading, in the light of the exact tests and classification permitted by later scientific knowledge of heat and its application to power purposes. These differences of opinion were, however, of a minor character, compared with those which beset engineers called upon to consider power schemes at the present day. The steam engine is but one of many types of prime movers available, each with its distinctive features, limitations, and subdivisions claiming special advantages or conveniences. The turbine may be operated by impulse or reaction or a combination of both. It may be arranged horizontally or vertically. The gas engine may be four-cycle or two-cycle, and the latter again single-acting or double-acting, while it may be operated with producer or suction gas. The same with the oil engine, which is even more widely differentiated, for, in addition to the cycles and methods of action, we have subdivisions according to nature of fuel, whether petrol or heavy petroleum; and also according to method of ignition, whether by an extraneous source or by the heat of compression as in the Diesel, or a combination of both as in the semi-Diesel. Upon the multitude of claims to merit put forward by advocates of the various types it is not easy in particular cases to adjudicate, however well versed be the engineer in general

knowledge of the subject, and it is impossible to be expert in every branch, though fairly cognisant he must be if he is to avoid serious error in selection. Superimposed on all this are other matters, such as superheating and the extent to which electricity may be employed either as a prime mover or a subordinate agent in power transmission. To keep au-fait with the subject demands constant study and familiarity with current literature, for opinions that may be justified to-day may be wrong to-morrow. One has but to briefly glance at the later phases of power development to be impressed with this fact. The turbine and the Diesel motor serve as illustrations. It is not long since the Parsons turbine appeared to be the only practicable one available, but while it retains a large field within which rivals have little room for competition, there is ample scope for various other types that have been evolved since Parsons demonstrated the utility and efficiency of this type of prime mover, and opinions based on an experience of the working of his design alone would not be suitable for general application. The relative advantages of the various types are becoming more and more closely defined and practice correspondingly fixed. The Diesel engine at present is passing through a period of transition and experience is being purchased as it always has to be, more or less, by trial and error. It is only some 13 years ago, when one of about 7 h.p. was exhibited at Paris, that it entered the lists of competing prime movers, and though its theoretical advantages then attracted attention, it was not until several years afterwards that it began to make serious headway. Its progress since has, however, been rapid, as is but natural with a motor capable of utilising 40 per cent. of the theoretical power of the fuel supply, or practically double the efficiency of the gas engine, which from this point of view leaves the steam engine far behind, though incidentally this feature serves to illustrate the dangers that beset the path of theoretical pre-eminence and the numerous considerations that have to be taken into account in selecting a prime mover in practice. Fuel efficiency is but one of many factors that have to be considered, and, without reference to cost of fuel, may easily mislead. The steam engine with its necessary boiler seemed to have a poor chance of surviving in face of its gas and oil rivals with their high standards of efficiency, but for the great bulk of power requirements it more than holds its own, and, so long as a plentiful coal supply is available, is likely to do so. The Diesel principle has, of course, powerfully attracted ingenious minds and led to remarkable developments. The 7 h.p. unit shown at Paris has rapidly blossomed into units of 1,000 b.h.p. and upwards, but the troubles in these larger sizes have shown that rapid progress in mechanical construction is liable to be attended with disappointment. At all events, the experiments with the German battle-ships, in which it was proposed to develop 12,000 h.p. in six cylinders, resulted in failure, and led to the substitution of steam turbines. This, however, was a big step, and its temporary failure in no way detracts from the merits attained in smaller sizes not exceeding 250 h.p. per cylinder. Even for this power the refinements of mechanical construction are pretty heavily taxed. In the Diesel system ignition of the oil charge is effected by the temperature due to pure compression of the air charge, and only those familiar with pressures of 600lbs. and 700lbs. on the inch can appreciate the difficulties of dealing with them. Piston and cylinder require to be a beautiful fit. The difference of diameters is only a few thousandths of an inch, and in some cases only corresponds to a temperature difference of 100° Fah. With such minute clearances breakdowns through seizure of cylinder and piston are scarcely a matter of surprise, and needless to say, the utmost care and attention to lubrication are necessary to avoid them. These troubles with the Diesel engine have served to concentrate attention on what is known as the semi-Diesel type, in which lower compressions are used and in which either an independent source of ignition is provided or in which the operation is promoted by a vaporiser heated with the exhaust gases. This feature promises to greatly extend the sphere of usefulness, and the extent to which the motor is capable of utilising crude oil, whether as a residual petroleum or tar or the product of vegetable or animal matter, is undoubtedly a great point in its favour, while the lower compression and temperature tends to diminish risks of seizure troubles. As regards the pure Diesel type, the resources of mechanical ingenuity are not exhausted, and though for the moment there has been a set-back in respect to large units, the field of application with 250 h.p. cylinders is very wide. The ability of the motor to start at a few seconds' notice is a great convenience when intermittent loads have to be dealt with, and the fact that when it is stopped there are no banked fire losses is often an advantage of a substantial kind.

TESTING FOR FIRE-DAMP.

At a recent meeting of the Mining Institute of Scotland, the discussion was resumed on the paper read by Mr. Henry Briggs, Heriot-Watt College, Edinburgh, on "Testing for Fire-damp and Black-damp by Means of a Safety Lamp." Mr. J. Balfour Sneddon said it would be recalled that at the last meeting of the Institute a desire was expressed for further trials of the loop device so strongly advocated by Mr. Briggs. Accordingly a series of tests arranged for by Mr. Wm. Walker, H.M. Inspector of Mines, had been carried out at Valleyfield Colliery, belonging to the Fife Coal Company, and Bothwell Castle Colliery, belonging to Messrs. Wm. Baird & Co. Personally the trials had proved to him that the loop in the hands of an expert did show a gas cap clearer than the lowered flame did in the case of the smaller percentages. The conclusion he had come to was that Mr. Briggs had given them a device that required probably more skilful handling, but this could be acquired, and the more accurate and better results got would well repay the trouble taken. Mr. William Walker, H.M. Inspector of Mines, said he thought there was something to be said for this device, chiefly because of the fact that they could detect with it the presence of gas in smaller percentages sooner than could be done with the lowered flame. His suggestion was that the committee of the Institute who had already tested with the loop should be continued in office and that further trials should be made by practical firemen and colliery managers. Prof. Burns, Glasgow, said the committee, of which he was convener, had come to the conclusion that the naked flame without the loop was better as a gas-testing device than the loop itself. He still adhered to that opinion. Mr. Henry Briggs, in replying to the discussion, said he had advanced certain claims in regard to the utility of the loop in black-damp testing, yet the report by the committee of the Institute made no mention of black-damp, and hence he concluded they made no tests on that mixture. Although the loop as an indicator of black-damp was only a rough device it possessed, he thought, some claim to attention as being the only means at present known of enabling an estimation of that impurity to be made with a safety lamp. It was remitted to the Council of the Institute to arrange for the appointment of a committee to carry out further experiments with the loop.

PETROL AND TRACKLESS TROLLEY VEHICLES.

AT the recent annual conference of the Municipal Tramways Association held in Sunderland, Mr. C. J. Spencer (Bradford), in the course of a paper on "Petrol and Trackless Trolley Vehicles," said it was common ground that some cheap form of transit was needed in many districts where tramways proper were prohibitive owing to the heavy capital expenditure. He left out of consideration the experiences with the very early types of railless trolley vehicles and motor-'buses, and considered what they might reasonably expect with vehicles constructed in the light of modern experience and capable of efficiently providing public service. The modern motor-'bus certainly did not run so smoothly as a rail-borne car, and could not be expected to do so. With the motor-'bus the noise of moving machinery was reduced to a minimum, and with proper maintenance and care should not exceed the tramcar in that respect. But whatever might be the case at present, it should be possible to construct railless trolley vehicles to run more quietly and with less vibration than motor-omnibuses. The absence of spur-gearing, or chains, in the case of future railless trolley-cars was bound to result in less vibration and noise, and consequently smoother running, than could possibly be the case with the internal-combustion types. With regard to convenience and facility of operation, it had been argued that there was a considerable advantage in a railless trolley extension system in connection with an existing tramway system of considerable size, on account of the fact that, after all, a railless trolley-car was little more than a tramcar running on road wheels, the overhead equipment being the same. On the other hand, if a small number of motor-'buses were purchased the position was altered; their design was altogether different from a tramcar, their inspection and maintenance were of a far higher order, and quite another type of fitter and staff was required to handle them, and, where their number was small, it was difficult to get the fullest economy and efficiency from a special staff. An average figure for traffic expenses in a semi-industrial area would be 2·67d. for the motor-'bus and 2·5d. per car-mile for the railless-trolley vehicle, the extra ·17d. for the motor-'bus being for lubrication. General expenses, with two exceptions, might be assumed as common to both. The rates on railless trolley-cars were, as the law stood at present, in excess of those paid for omnibuses. So far as his knowledge went, the railless trolley-car was rated on its revenue-earning capacity, and the petrol omnibus on the rateable value of the garage. What the ratio of these two figures really was he could not say. On the other hand, he thought it might be fairly argued that the liability to accident with a railless trolley-car was less than with a motor-omnibus, and certainly the amount paid for fire insurance would be higher in the case of the motor-omnibus. General repairs and maintenance, he estimated at 1·79d. for the railless trolley-car and 2·24d. for the motor-omnibus, and power at 2d. per car-mile for petrol and 1d. for electric energy. On this basis the total cost per car-mile of running the respective vehicles was 6·09d. for the railless trolley-car and 7·71d. for the motor-omnibus. Turning to capital costs, he considered that the petrol vehicle was the more expensive, and if they took its useful life at 100,000 miles and the capital cost at £850, with a life of five years, they would have to pay a sum of 2·27d. per car-mile for interest and depreciation charges. In the case of the railless trolley £750 should be a fair cost of the vehicle, and with a life of 10 years, or 200,000 miles, the cost per car-mile in interest and depreciation charges would be 1·09d. Thus the total cost, including capital charges, was 9·98d. for the motor-omnibus and 7·18d. for the railless trolley car.

PREVENTION OF EXPLOSIONS IN MINES.

THE views recently expressed by Dr. Harger, of the Liverpool University, as to fire-damp in coal mines were discussed at a recent meeting of the Manchester Geological and Mining Society. Dr. Harger, in papers read before this society, submitted that if the quantity of oxygen in the air of a coal mine were diminished, say to between 17 and 18 per cent., there would be an end to disastrous explosions and gob fires. He also submitted that men could live and work in such an atmosphere. These views have been challenged by mining men, chemists, and others.

Mr. Noah T. Williams, Lecturer in Mining at the Manchester University, starting the resumed discussion, said the detection and estimation of fire-damp in mines was a matter of importance to mining men, and he was in full accord with Dr Harger that coal gas was not a very satisfactory substitute for methane for the purpose of training men in "gas caps." Analyses of coal gas supplied by many gasworks in South Wales showed clearly the variation in the composition of the gas. For instance, the nitrogen present varied from 3 to 24 per cent. Identical "caps" for the same percentage of gas and air could not be expected from such a variable mixture, nor would such "caps" have exactly the same qualities as those obtained from fire-damp and air. The proposal made by Dr. Harger, Mr. Williams added, of reducing the oxygen in the air for the prevention of explosions was a very serious one both from the physiological and commercial point of view. Rightly to gauge the percentage of oxygen necessary and to be confident that such a reduction would not be injurious to life appeared to him to be a very difficult problem, and the margin must be a narrow one. Some men were stronger and would be better able to withstand these effects and continue work longer than others, but all men would have to accommodate themselves daily to the abnormal atmosphere of the mine.

Dr. Coward, of the Manchester Municipal School of Technology, directed attention to points raised by Dr. Harger in connection with the chemical problem associated with the gases present in fire-damp. It was surprising to him, he said, to read that Dr. Harger's methane was "often contaminated with considerable amounts of nitrogen from leakages and from the water," for leakages could be avoided, and the use of liquids other than water—such, for example, as a mixture of equal volumes of glycerine and water—would reduce the nitrogen content of the gas to a minimum without adding much to the cost of the preparation. A more important point was the question as to whether a mixture of methane and air was inflammable when the oxygen content of the air had been reduced below 17 per cent. Dr. Harger's experiments, unfortunately done with a gas with the purity of which "he was not at all satisfied," were in sharp contrast with the statements of G. A. Burrell. On the other hand, experiments made some time ago by Clowes and Failmann and by Eitner were quite in accord with Dr. Harger's conclusion. The whole argument, in Dr. Coward's view, had evidently been based only on the scantiest experimental evidence, which was totally inadequate to permit definite conclusions to be drawn.

Mr. Albert Parker, of the Manchester University (chemistry department), said that experiments had been conducted recently in the chemical laboratories of the Manchester University on the inflammability of methane with air containing diminished oxygen, and it had been found that methane could be exploded, or rendered inflammable, when mixed with air containing only 13·5 per cent. of oxygen and the rest nitrogen. Not many experiments had been conducted so far, but they were being continued, and it was hoped the University chemists would be able to furnish further results within a short time. This particular result showed, however, that methane could be exploded with air containing less than 17 per cent. of oxygen.

The Society of Engineers.—A large party of members of this society visited the Chingford Reservoir of the Metropolitan Water Board on Tuesday afternoon, the 17th inst., for the purpose of inspecting the reservoir and the Humphrey pumps that are installed there. The reservoir has a capacity of 3,000 million gallons, an area of 416 acres, and 4½ miles of embankments, and water is raised from the River Lea by means of five Humphrey pumps, four of which have a capacity of 10 million gallons per day and the fifth of 20 million gallons per day, the lift being 25ft. to 30ft. The pumps, which are the invention of Mr. H. A. Humphrey, M.Inst.C.E., employ the principle of internal combustion, and have no moving parts except the mushroom valves. A column of water, forming part of the water pumped, acts as a reciprocating flywheel, and also as a piston, having four strokes in each cycle. An explosive charge is ignited nine times per minute in each pump, and 15 tons of water are delivered at each explosion. The visitors greatly appreciated the opportunity of viewing this novel and ingenious application of a well-known principle.

THE PRODUCTION OF SOUND STEEL INGOTS.

BY LESLIE E. HOWARD,

THERE is probably no manufactured article made of steel in which the production of absolutely pipeless and sound ingots is of more importance than that of saws. Seven years ago experiments were commenced by the Simonds Manufacturing Company of Fitchburg, Mass., aiming to develop a method for the production of sound ingots especially for the manufacture of saws, and the method and apparatus briefly described below, for which we are indebted to "The Iron Trade Review," is the outcome of this long series of experiments.

When it was first suggested that the ingots commonly used in crucible steel mills be made sound by fluid compression, it was felt that it would not be practical to develop a method and apparatus that would handle the very small ingots which it would be necessary to operate on, and it was found by investigation that practically no plants were in operation working on ingots of much less than a ton weight.

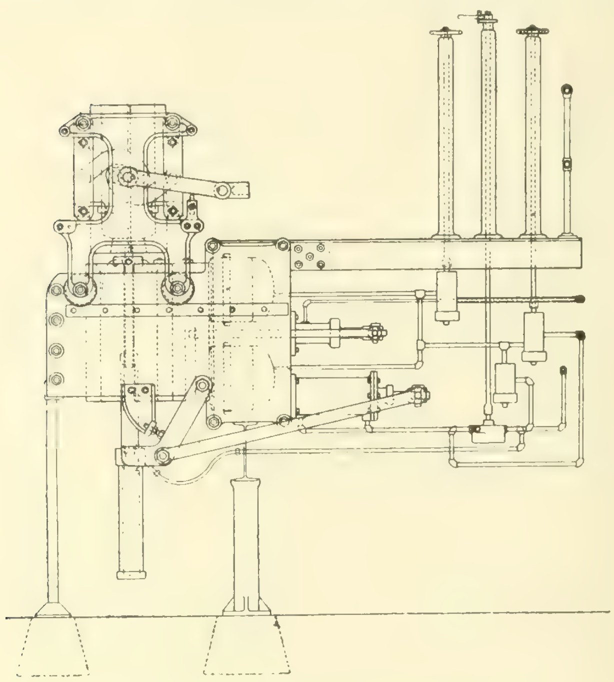

FIG. 1.—GENERAL ARRANGEMENT OF INGOT PRESS.

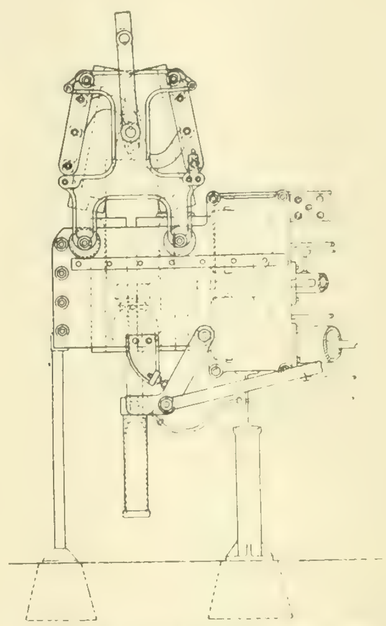

FIG. 2.—VIEW SHOWING FRESH INGOT BEING LOWERED INTO THE PRESS.

Having this in mind, the first experiments were made on small ingots weighing but 15lbs. each, and it was found that there was no difficulty whatever in producing these absolutely sound and without blowholes or pipes. The next experiments were made on slightly heavier ingots of rectangular cross-section 3½in. by 5½in., and weighing about 110lbs. A pressing unit was then built capable of handling one 400lbs. ingot or two 200lbs. ingots at each heat, and, with modifications from time to time, this arrangement has been found very satisfactory. At present there are, at the steel plant of the Simonds Manufacturing Company at Lockport, New York, eight presses in continuous operation, making ingots ranging from 180lbs. up to and including 600lbs. in weight.

Early in the series of experiments above referred to, it was found too expensive to compress ingots in the same moulds in which they had been poured. It was found that an ingot of approximately square cross-section could be operated on more satisfactorily than any other (excepting round or octagon), although ingots have been made satisfactorily by the process with a cross-section 4in. by 8in. and 8in. by 12in., and weighing respectively 350lbs. and 600lbs.

Another feature which our first investigations revealed was that practically all attempts to compress ingots by lateral pressure previous to the method outlined had been along the lines of placing a large number of moulds tandem style in one pressing unit, and investigation as to the effect of this arrangement showed conclusively that there is practically only one ingot in the series that could possibly receive proper treatment. Aside from this, most of the apparatus of this nature was rather cumbersome and expensive to operate, and the press had to be practically dismantled to get the ingots out after they had been operated on.

It was, therefore, considered desirable to set to work on the lines of producing an apparatus possessing the following general features: (1) Have the units small and extremely simple so that if one unit was out of order for any reason, it would not in any way affect the rest of the plant. (2) Design these units so that the plant could be added to and the system extended at will, and, at the same time, have each unit entirely separate and independent of the others so that it could readily be lifted out of its place with a crane if out of order or damaged, and a spare unit put in its place. So far, it has never been found necessary to do this, but it was considered desirable to have this in mind in developing this method. (3) Be able to operate on the ingots in such a way that every individual ingot receives precisely the amount of pressure and time necessary to get the best results without reference to any of the other ingots being cast at the same time. (4) Develop a mechanism that would be so extremely simple and rugged that it would not require a different type of labour to operate than is commonly found in melting shops.

In addition to the above considerations, it is, of course, obvious that a plant of this nature to be commercially successful must not involve a large investment as compared with the returns, and that the operating costs must be extremely low.

In a general way, the method consists of casting the ingots in moulds made of special cast iron, and, while the ingots are still internally fluid but sufficiently set so that they will not burst by careful handling, they are transferred mechanically to steel compression dies, where they receive lateral or side compression of from 1½ to 3 tons per square inch of greatest area of cross-section operated on, this pressure depending largely on the composition of the steel, temperature of the steel when poured, &c.

Fig. 1 shows the general arrangement of presses for handling ingots up to 1½ or 2 tons and as small as may be desired, and as many of these presses as are necessary for a given output are arranged side by side, supported in any suitable way, dependent on local conditions. An extension of the back end of the press serves as a support for a working platform, which is made continuous from press to press, this working platform on the smaller size presses being approximately 3ft. wide, and the length of course varying with the number of presses in the installation.

In the case of ingots up to the sizes mentioned above and also up to and including 3,000lbs., split moulds are satisfactory and desirable, as they greatly facilitate the stripping operation, and, on account of the very short time which the ingots are in the moulds, there is an entire absence of warping and distorting of the moulds commonly met with in split moulds, where the ingot is allowed to cool entirely in the moulds to a point where it usually is stripped. Moulds are in use in Lockport at the present time which have been running eight months night and day, and are just beginning to show slight cracks in the side walls of the moulds. They are good for another six weeks or two months.

Referring to Fig. 1, it will be noted that the press proper is of a box form, this being found desirable on account of the great strength for the total weight of the completed press and for the low cost of machining, aside from making it very rugged and not easily damaged by rough handling. The hydraulic compressing cylinders form one end of the "box" and a heavy steel casting forms the other end, these two

members being tied together by cast steel side stress members, inter-locking joints being provided, so that the greater the strain between the back head and the rams the more closely do the side members pull in on the cylinders and back head. The tie rods holding all of the press members together have, therefore, only to keep the members in place when there is no load on the rams or when handling the units.

A simple retracting arrangement for the crosshead and hydraulic rams is provided, which, in the case of the smaller size units, is usually a spiral spring, and which, in the larger sizes, is a hydraulic cylinder of very small cross section relative to the cross-section of the pressing cylinders, and which is piped to the high-pressure supply without any provision being made for valves or control.

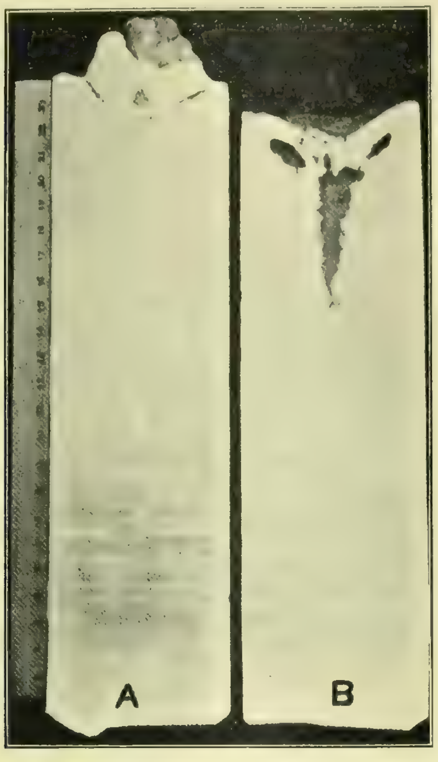

FIG. 3.—SECTIONS OF COMPRESSED AND UNCOMPRESSED STEEL INGOTS

The mechanism for lowering the partly-cooled ingots from the moulds into the compressing dies consists of a hydraulic cylinder and ram carried on two swinging arms (one on each side of the press), so that it may be brought out of vertical alignment with the dies when desired and leave the pit under the dies absolutely clear and unobstructed. The mechanism for accomplishing this consists of a small low-pressure cylinder usually mounted on the back end of the press and provided with a simple cross-arm and connecting-rod arrangement controlling the movement of the swinging arms carrying the lowering ram cylinder referred to above. The controlling valves and mechanism are extremely simple. All of the movements of the ingot after it leaves the mould are accomplished by one low-pressure controlling valve, the handle of which, when moved from notch to notch, causes each of the parts to function properly and in their proper order. The high-pressure cylinders are controlled by a simple form of stop valve and a simple one-way valve for discharge.

Mounted above the compressing dies is a mould-carrying rack, shown clearly in Fig. 1. The moulds are split ones, and in the smaller sizes this mould-carrying rack is operated by hand, and in the larger sizes by a small hydraulic cylinder mounted on the side of the press frame, not shown in Fig. 1. Ingots of various cross-sections have been operated on by the regular equipment, but the present moulds and dies are designed and built for pressing the ingots cornerwise, that is, with one of their cross-section diagonals at right angles, and the other normal to the direction of compression. Ingots of square cross-section have been found to work out better, not only from the compression standpoint, but also for subsequent operations in the mills.

The bottom of the split mould referred to is formed partly by a removable round taper block carried on the lowering ram, and so arranged that when the moulds are "set up" this lowering ram is in its uppermost position, and the taper block forms a bottom closure to prevent steel from running through the bottom of the mould. It is found that these blocks or mould bottoms take practically all the wear of the mould, such as the cutting effect of the stream of molten steel when pouring, and they are practically the only parts that have to be renewed under seven or eight months, and these ordinarily last when running night and day on one 30 pot furnace from two to three months. The method of operation on ingots with this apparatus is as follows:

The moulds (having been previously well smoked before removing from the racks) are locked together by the toggle arrangement shown in Fig. 1, and the lowering plunger is brought to its uppermost position, so that the bottom of the mould is closed by the taper block. The controlling valve on the high pressure cylinder is, of course, closed and the discharge valve open, and the dies are thus opened to a predetermined point. The moulds are now poured by any approved pouring device. After pouring, the ingots are allowed to set a pre-determined length of time, depending on their size, composition, &c., but in any event just as short a time as is necessary to form a light skin which will not burst open when the ingots are stripped. This time varies from one to five minutes on ingots from 150lbs. to 600lbs. in weight and of varying compositions. The stripping mechanism is now operated, so that the moulds occupy the position shown in Fig. 2 (which shows the ingot partly descended into the dies), leaving the ingot supported at the top end by the moulds (which are not opened much if any at their top ends) and by the taper block at the bottom end, which forms the bottom closure of the mould during the pouring.

The low-pressure controlling valve handle is now moved one notch, causing the ingot to descend into the compressing dies, the speed of this descent being controlled by a stop cock in the discharge line. The lowering cylinder is provided at its lower end with a spring or in some cases with a hydraulic stop, so that the ingots are brought to rest very gently and in a position suitable for the pressing dies to operate on them. The high-pressure release valve is now closed, and the low-pressure controlling valve handle is moved to the next notch, causing low-pressure water to flow from the low-pressure supply through a high-pressure check valve into the high-pressure compressing cylinders, and the compressing dies are thus rapidly moved up to and in contact with the ingots and the cylinders filled with water under low pressure, usually 100lbs. to 125lbs.

The high-pressure controlling valve is then opened very slightly and compression is commenced. At this point, the ingots are still fluid internally, and have not begun to show the slightest sign of pipe or sinking in the top end. The compressing cylinders are allowed to come up very slowly indeed, so as to just keep the ingots from forming pipe, and this is continued until by experience it is known that the ingot is very near the point of setting or becoming solid throughout, when the pressure is increased slightly, and a small amount of the last portion of the ingot to cool is squeezed out of the top, this, of course, being the liquated portion. This liquated portion contains practically all the segregation, and is decidedly higher in phosphorus, sulphur, and other impurities than the metal left in the ingot. This liquated portion forms a rough ball-like knob on the top end of the ingot, and is practically the only portion of the ingot not suitable for finishing, and in weight varies from 2½ to

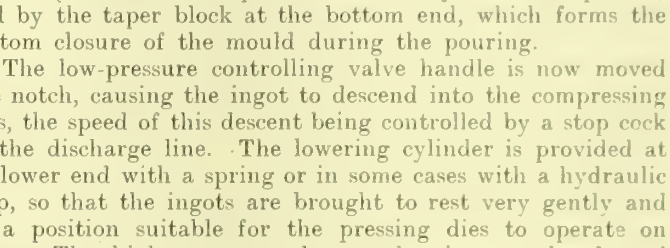

FIG. 4.—SECTION THROUGH HYDRAULIC VALVE

4 per cent. of the total weight of the ingot. This squeezed-out knob is shown in Fig. 3A.

As soon as the compressing dies have a good grip on the ingots so that there is no possible danger of their dropping through into the pit, the low-pressure controlling valve handle is moved to the fourth notch, causing the low-pressure cylinder to move the ingot-lowering cylinder out of vertical alignment with the compressing dies, and the controlling valve is then left in this positon until compression is completed. The pressure is kept on the ingots for a considerable time after they have ceased to "rise"; in fact, after they have reached the point where they are considered solid, the pressure is quite materially increased and the ingots then receive what is virtually a hydraulic forging treatment, which tends to break up the coarse crystals formed in cooling into a fine crystalline structure much resembling an ingot worked under a hammer or forging press.

FIG. 5.—SHOWING SWAGING GIVEN TO SAWS

When the operation of compressing is completed, the high-pressure control valve is closed and the discharge valve opened, when the dies immediately retract and the ingots drop through into the pit, and this may be provided either with a bottom of sand, so that the ingots may be given a partial annealing before going to the stock piles, or the ingots may be dropped upon cars or a conveyor.

Fig. 3A shows a 400lbs. ingot which has been subjected to this treatment and split longitudinally, while Fig. 3B is an ingot poured at the same time, weighing slightly less on account of its decreased length and not compressed. The presses do not require to be dismantled to discharge the ingots, and the operation of setting up for another heat takes but a few minutes. In fact, the first of the presses to be poured are quite often set up before the last of the series have dropped their ingots. The total operation of setting up eight presses occupies but 10 or 12 minutes, the greater part of which is used in smoking the moulds.

One man easily operates eight presses, which are so designed that they may take care of two to three 30-pot crucible furnaces, providing all the furnaces are running on the same size of ingots, so that it is not necesary to change the moulds and dies between the heats, as the presses are amply provided with cooling facilities so that the parts do not become overheated.

It is obvious that with the hot ingots in contact with the mould walls only about one-twentieth of the time usual when they are allowed to cool in the moulds, the moulds do not get overheated, and no artificial cooling of any kind has been found necessary. The crosshead and, on large presses, the compression dies are water-cooled. The high-pressure cylinders are also piped, so that when they are not under actual load, low-pressure cooling water may be circulated through them, thus keeping the rams and packing leathers at a reasonable temperature. No trouble has been experienced with packing leathers, all of these having on an average run 10 months night and day without renewal.

The pressing dies are of cast steel, and in the equipment described there are two grades, one-half of the dies being 0·40 per cent. carbon, and the remainder 0·70 per cent. carbon steel castings, but up to the present time there is no appreciable difference in their performance, as all of the dies show practically no signs of wear, and should last at least one year without replaning, and as the design has made allowance for at least seven or eight replanings, they should last four or five years without renewal.

One point of special advantage in changing from one size ingot to another is that there are absolutely no fastenings of any kind holding the moulds or dies to the other mechanism, excepting that the moulds are provided with loose links which drop over one of the cross bars in the mould rack, and can be readily lifted out by hand or by using a pair of tongs. The moulds are usually lifted out of the rack with the crane in pairs, special hooks being provided for this. The compression dies are lifted in or out of the press frames, and gravity alone keeps them in place. The retraction of the movable dies is accomplished by a loose fitting link, one end of which engages a pin in the top end of the movable die, and the other end a pin in the top end of the crosshead, and this is readily lifted off and on with tongs or by hand.

The plant at Lockport is served by a single-acting triplex high-pressure pump with 1¼in. rams and 8in. stroke and driven by a 15 h.p. motor, and the low-pressure supply is obtained by a 3½in. by 4in. triplex single-acting pump running at 100lbs. pressure, and driven by a 3 h.p. motor. As these pumps are only run about one-half hour at each heat, it is obvious that the power consumption is extremely low. Both pumps have a common supply tank, and the discharge from the cylinders is piped back to this tank. This portion of the plant was so designed that, if found desirable, during the extreme cold weather incurred at Lockport, a solution of alcohol and water could be used to guard against freezing, but so far this has not been found necessary, as the radiated heat from the adjacent furnaces has been sufficient to obviate any trouble from freezing.

All of the hydraulic valves on the high-pressure side of this system are designed on the lines shown in Fig. 4, so that the valve and valve seats can be removed very readily for repairs without breaking any pipe connections. The time for making a change on any of these valves never exceeds 30 secs., and on a test has been done in 9 secs. It has been found desirable also to equip the hydraulic pump which operates at 4,500lbs. pressure with valves of this general type, so that there is never any shutdown or stoppage on account of leaky valves.

Some of the results obtained from the use of this method are extremely interesting. Probably one of the most severe tests which could have been made was in the manufacture of shingle saws, which run in sizes from 36in. to 42in. diam., and while they are 9 to 7 gauge thick at the centre (where they are ground "straight" for a collar or reinforcing plate), they taper from that collar to the rim until they are only 14 or 16 gauge at the rim or cutting edge. These saws are left just as high temper as possible to file them properly in fitting and, at the same time, nearly all of them are "full swaged," as shown in Fig. 5, thus imposing a very severe test on the material, even when the steel is absolutely sound and normal. While going through some tests on special steels, it was decided to determine how close these saws might be taken from the top of an ingot and still stand the severe swaging tests. The results were very satisfactory indeed, and several ingots were cut in such a way that one side of one saw from each ingot was only ⅜in. from the normal top line of the ingot. Every one of these went through perfectly sound. Later, field tests on these saws indicated that there was no difference whatever in the quality of the saws, whether they were made from the top or bottom portion of the ingot.

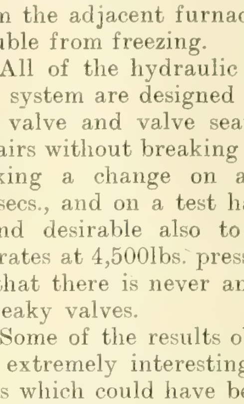

FIG. 6.—DOUBLE-CUT BANDSAW

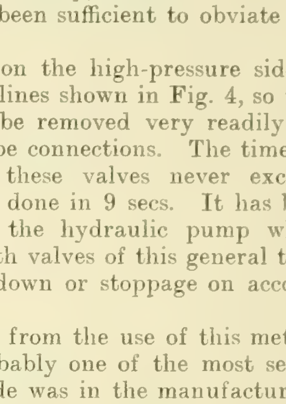

FIG. 7.—DOUBLE-CUT BANDSAW SPLIT AND INSIDE EDGES TOOTHED.

Another test which indicates the absolute soundness of the ingots obtained by this process was made on large bandsaws. Fig. 6 shows what is known as a double-cut bandsaw, that is, a bandsaw having teeth on both edges, and these also are full swaged, as shown in Fig. 5. These saws range in size from 6in. of 16 gauge up to as large as 18in. of 11 gauge, and it is apparent that any unsoundness of any kind would render the saw worthless. Several 12in. saws were taken at

random and split lengthwise from end to end and the "inside" edges toothed, when they presented the appearance shown in Fig. 7. These were then swaged so that each tooth presented the appearance shown in Fig. 5, and there was not a single indication of split or pipe anywhere in any of the saws, proving conclusively that the steel must have been sound and free from pipes and blowholes from top to bottom of the ingot, as these bandsaws are cut very close to the top of the ingot at the present time.

Several ingots were cut open longitudinally and the exposed surfaces planed and polished and a careful study of the structure made, and, so far as these tests have gone, they show that the ingots were homogeneous, and with an entire absence of segregation up to ingots of 600lbs. in weight, and that the structure of the steel as it leaves the compressing dies is absolutely uniform. Test pieces cut from these ingots without any work of any kind being done on them have shown that steel taken from the top centre of the ingot where the pipe usually forms gives precisely the same physical tests as test pieces cut from other portions of the ingot, while in uncompressed ingots the centre of the ingot, even in the lower half and bottom end, does not test out nearly as well as pieces cut from the sides.

In general, the method is not intended to be a curative one, as tests made in our early experiments proved to us conclusively that if a pipe in an ingot had once developed and sulphides and oxides formed on the surface of the cavity, it was practically impossible to weld it up or cure it in any way. The method, however, is preventive and most effectively prevents a pipe forming. Various grades of steel have been operated on that may be made in a crucible or electric furnace, but practically all of the tonnage so far handled is tool steel used in the manufacture of saws and machine knives, this including straight carbon steels of the usual carbon content for the purpose noted, as well as low alloy steels. It has been found, however, that in the case of strictly high-speed and semi-high-speed steels the apparatus must be handled carefully and the ingots at once annealed after pressing, this being necessary owing to the increased density of the already very dense material, due to compression. Great care must also be taken in re-heating ingots of this type that the heat is brought up slowly and uniformly to prevent the ingots bursting.

The plant as described above has been working night and day for over a year, and at present all of the bandsaw and circular saw steel, excepting the very small circulars, is made from compressed material. It has been found that the total cost of operating this plant is less than 3 per cent. of the value of ingots operated on, and this will be reduced somewhat when the new equipment is completed, as a greater tonnage of ingots will be handled, with no increase in labour cost and a decrease in capital charge. Experiments are also under way for a modification of the device to be used, especially on large ingots in which the split moulds are replaced by the usual form of solid tapered moulds handled by an ingot stripper. The process and apparatus is fully covered by patents granted to the author and assigned to the Simonds Manufacturing Company.

Accident to a Naval Airship.—The naval airship "Astra Torres" was brought out at Farnborough on the 12th inst. for a trial flight. Unfortunately, the pressure could not be maintained, as the belt which drives the fan, by means of which the pressure in the balloon is maintained, was slipping badly, and as a result the envelopes began to sag. The pilot in charge thereupon decided to land, the airship coming down on Farnborough Common, where she was safely re-housed, and will continue her trials after the necessary alterations have been made. The airship is approximately twice the size of the largest Army dirigible and half as big as the average Zeppelin. Her length is 260ft. and her breadth 50ft. The envelope is in three lobes similar in shape to a shamrock leaf. It is made of cotton fabric and rubber, and has a capacity of about 300,000 cub. ft. The lifting power of the envelope is estimated at seven tons. The airship is capable of carrying a crew of 10 persons for 800 miles (a 20 hours' journey) and two tons of petrol, the amount necessary for such a trip.

PETROL-ELECTRIC MOTOR-VEHICLES.*

BY J. B. G. DAMOISEAU.

(*Continued from page* [illegible].)

SWEDISH STATE RAILWAYS MOTOR VEHICLES.

THE petrol-electric motor-vehicles at present undergoing trials on the Swedish State Railways are particularly interesting because they are the first to be equipped with Diesel engines for use on railways. This type of engine has been introduced in order to reduce the cost of fuel, which was considered too high in the case of the petrol engine. These cars are of the petrol-electric type with electric transmission. Each motor vehicle has a Diesel engine of 75 h.p. at 700 revs. per minute, coupled to a 50 kw. continuous-current generator feeding the two electric motors, each of 30 h.p. The generating set is placed crosswise in one of the two driver's cabins.

The Diesel engine used has six vertical cylinders, water cooled, and also a supplementary cylinder for supplying the compressed air necessary for starting the engine and for injecting the petrol for starting. This engine, which is provided with a governor, drives an oil pump, and a compressor for supplying the air for the brakes. The silencer placed under the car is supplied by a pipe carried on to the roof. The radiator is also placed on the roof. The water for cooling the engine is circulated by a pump driven through gear by the engine. The reservoirs for the oil fuel are in the cabin containing the generating set, and the water reservoir is lodged in the baggage compartment. The supply of fuel and water is obtained by means of a hand pump in the cabin. The fuel consumption is said to be 225 grammes of oil per horse-power hour at the full load of 75 h.p.

The generator gives a variable pressure from zero to a maximum of 440 volts, according to the speed of the engine. It has commutating poles and is connected to the engine by means of a leather-belt flexible coupling. The engine and generator stand on one bedplate. Each driver's cabin contains the necessary apparatus for starting the car and for putting on the brakes; also the controller (which has two handles), a wattmeter, a brake cock, air whistle, &c. A battery of 23 cells and of 200 ampere-hours capacity is automatically connected with the generator when running without load, *i.e.*, when the car is at rest or running down an incline. This provides the lighting of the car, as well as supplying the auxiliary apparatus used in working the car.

The speed of the engine is regulated by a small electric motor operated from the controller. The starting of the car is effected as follows: The petrol engine having been started by means of compressed air, and the "forward-reverse" handle of the controller having been moved to the notch for the direction required, the driver of the car presses the button on the second handle of the controller so as to cut off, by means of the main switch, the circuit of the generator and the two traction motors, which latter are connected in parallel; then he moves the handle gradually from the "stop" position, at which the engine runs at 350 revs. per minute, to the position of full speed, which corresponds with a speed of 700 revs. per minute. During this procedure the speed of the engine is gradually increased by means of the small control motor, and the car is started without any loss of energy, as no starting resistances are employed. When the normal speed of the engine is reached, the regulation of the car's speed is effected automatically, the design of the generator and of the electric motors being such that the power taken from the petrol engine is remarkably constant and cannot exceed the maximum power that the engine can give.

The arrangement to ensure the greatest measure of safety in working is as follows, one attendant only being required. On the roof of the car and on each side wooden bars have been fixed for keeping a spring mechanism in position. If the car passes beyond a signal which is at danger, one of the bars strikes an arm fixed to the signal, opens a switch in the motor circuit, and puts the air brake in action, thus stopping the train. An auxiliary emergency brake placed in the compartment for passengers allows the above mechanism to be similarly operated, should this ever be necessary. These motor-vehicles are of the 3-axle type, in which two of the

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engines are cooled, and comprise a driver's cabin (containing the electric generating set), a baggage compartment, a passenger compartment with seating accommodation for 39 passengers, a platform for access to the passenger compartment, and a driver's cabin. They weigh 26 tons and are built for a maximum speed of 60 km. per hour. The electric equipment was supplied by the Allmänna Svenska Elektriska Aktiebologet.

Motor-vehicles of the Pieper Type.

The principle of all the previously described cars consists essentially in the total transformation of the mechanical energy of the internal-combustion engine into electrical energy, which in turn is transformed into mechanical energy at the axles of the car. These cars have electrical transmission. The automobiles on the Pieper system are of the mixed-transmission type, with energy storage and regeneration. In this system the internal-combustion engine drives the axles directly by means of a cardan shaft and bevel gear. A shunt dynamo fixed on the engine shaft is connected to a battery of accumulators. This dynamo can operate as a generator or as a motor by regulating its excitation. When the power of the engine is insufficient, the battery automatically supplies the supplementary energy to the dynamo, which then receives energy and operates as a motor. When the power given by the engine is in excess of that required for traction, or when the kinetic energy of the car can be recuperated, *i.e.*, when the car is slowing down or running down a gradient, the dynamo works automatically as a generator and charges the battery.

The admission of the gas to the engine is controlled by an automatic regulator consisting of a differential solenoid with two windings. In one of these windings, that fed by the battery, a current flows continuously in the same direction; the other, a series winding, is in circuit with the battery, and the dynamo carries a current the direction of which varies. This "series" winding is arranged so that it reduces or increases the amount of gas admitted, according as the battery is or is not supplying power. An electromagnetic clutch is interposed between the engine and the axle, and the engine is able to rotate in either direction. Reversing is effected by means of an electromagnet controlled by either of the controllers. The type of controller used to drive the car has two handles, one serving the purpose of starting the engine in either direction, and the other for gradually regulating the speed and braking.

In order to start the car, the driver puts into action the electromagnet for changing the speed of the engine, by means of the controller, and starts the engine by sending the current from the battery into the dynamo, which is excited to the maximum. The engine having been started, the driver, by means of the other handle of the controller, admits current from the battery gradually into the electromagnetic clutch. This starts the car smoothly, and its speed is afterwards increased by gradually diminishing the excitation of the dynamo. The car having thus been put in motion, its control is afterwards effected automatically.

When the car reaches a gradient, should the resisting torque on the wheels become greater than the turning moment of the engine, the speed of the latter diminishes, the voltage of the dynamo falls and becomes less than that of the battery. The battery then discharging into the dynamo produces a torque which assists that of the engine until it balances the resisting torque of the car. The assisting couple produced by the motor is moreover a maximum, since the admission of the gas, which is governed by the discharge current, is likewise at a maximum.

Similarly, when the car arrives on a gradient, if the resisting couple is less than the turning moment of the engine, the speed of the latter tends to increase, the voltage of the dynamo rises so that the dynamo begins to charge the battery. This charging current passing through the regulator results in the rate of admission of the gas being reduced to the minimum and the torque of the engine becomes zero. For each section of the route, equilibrium is obtained between the three torques, viz., the torque of the car, the torque of the engine, and the opposing or motoring torque of the dynamo.

In order to slow down or accelerate at will the speed of the car, it is sufficient to upset this equilibrium. To slow down, the resisting torque must be increased; this is done by the driver increasing the excitation of the dynamo, which then begins to charge the battery. This charging current diminishes the rate of admission of the gas and consequently the driving torque. The loss of kinetic energy stored in the car is thus restored to the battery. For accelerating purposes the driving torque must be increased, *i.e.*, the excitation must be diminished. When the car is at rest, the engine clutch is disengaged. The engine may then be either stopped or changed to low speed in order to charge the battery.

This discussion shows that the internal-combustion engine owing to its constant connection with the axles of the car, and owing to the fact of its being automatically governed, works with variable cut-off. On gradients especially it runs at reduced speed and full admission, whilst on the level it runs at maximum speed and throttled cut-off. The internal-combustion engine must therefore be so designed that the total energy supplied during the various stages corresponds with the total energy developed during the complete return journey on the route in question, together with, of course, the loss of energy in the dynamo and the battery. This type of motor-vehicle, which requires accumulators, has also the advantage of storing energy when the car is slowing down or running down gradients. The motor-vehicles in operation on the Pieper system in France, by the Compagnie des Chemins de Fer de Grande Banlieue, from Saint-Germain to Poissy, are arranged as follows:—

The generating set with its two clutches is suspended on springs by two longitudinal girders from the frame of the car, between the two bogies, below the luggage compartment. This set drives the extreme axle of each bogie through a cardan shaft and bevel gear. The engine has four vertical cylinders of 155 mm. diam. and 200 mm. stroke, and piston valves are used. The engine is water cooled, is fitted with speed gear, and uses benzol as fuel. The silencer, the radiator, and the fuel reservoir are placed on the roof. The car has two driver's cabins, each supplied with a controller and the apparatus for operating the hand brakes and air brake. These brakes only act on the wheels. The heating of the car is effected by the circulation of the cooling water and the current for electric lighting is taken from the battery. The principal dimensions of the car are as follows:—

	Metres.
Distance from axle to axle of the bogies	8
Wheelbase of each bogie	1·775
Length of the body of the car	14·570

The car has two compartments, one first and one second class, situated on either side of the baggage compartment, which is in the centre. There are two platforms with side entrances between the two passenger compartments and the two driver's cabins. This car has seating accommodation for 12 passengers in the first-class and 21 in the second-class compartment, and standing room for 16. It weighs 21·7 tons, and can haul two 10-ton trailers on the Poissy—Saint-Germain line, which has a gradient of 50 mm. in a length of 500 metres.

The Thomas Petrol-electric System.

A motor-vehicle of this type with mixed transmission is in service on the Central South African Railway, on a line with a gauge of 1·167 metres. This car has a petrol engine, epicyclic gear, and two dynamos. The whole works on M. Gasnier's electro-mechanical method of varying the speed. The electric generating set is placed in the centre of the car and drives through a cardan shaft and gear the extreme axle of each of the two bogies. The gear box, which contains a double train of epicyclic gear, serves as a flywheel, and is directly attached to the engine shaft. A dynamo has its armature fixed on a shaft concentric with the engine shaft. On this shaft there is a small pinion which engages with the planet wheels.

When the speed of the car corresponds with the normal speed of the engine the whole of the gear remains stationary, and the gear box, the armature of the dynamos, and the shafts rotate as one piece. The transmission is then direct, and all the energy is transmitted as mechanical energy. When the speed of the car does not correspond with the normal speed of the engine the above parts undergo a corresponding displacement. Part of the energy of the engine is then transmitted direct through the gear as mechanical energy, and the remainder is transmitted by the dynamos, of which one works as a generator while the other receives electrical energy.

The dynamos are series wound and are permanently connected in series. The car is started and its speed controlled by varying the excitation of the two dynamos. The engine has

six vertical water-cooled cylinders, each of 178 mm. diam. and 228 mm. stroke, with high-tension magneto ignition, and develops 120 h.p. at 670 revs. per minute. It is capable of giving 200 h.p. when run at a higher speed. The radiator is placed on the roof of the car. Each of the dynamos can generate 50 h.p. for a period of 30 minutes, when running at a speed of 500 revs. per minute and weighs 454 kg. A battery of accumulators, which can be charged from one of the dynamos, the latter being converted in that case into a shunt dynamo, provides the lighting of the car and the starting up of the engine, and can, if necessary, drive the car. This battery is placed beneath the seats adjacent to the luggage compartment. The car has two driver's cabins.

The equipment allows the following processes to be performed: (1) The engine is started by supplying current from the battery to one of the dynamos, which then operates as a motor. (2) The car is started either forwards or backwards, and the speed is regulated by means of resistances in the exciting circuit of the dynamos. At full speed the two shafts of the dynamos, by means of a device operated by the controller, are locked together. (3) The battery is charged when the car is at full speed by one of the dynamos which has been converted into a shunt generator, resistances being inserted in the circuit. (4) When required the car can be driven by the accumulators. (5) Electric braking is provided, the dynamos running as generators when short-circuited through resistances. (6) The change in the direction of motion of the car is brought about by the change in the direction of rotation of the engine, which is stopped and then started in the opposite direction by means of the battery.

The following are the dimensions of the car:—

	Metres.
Gauge	1·067
Distance from axle to axle of the bogies	7·450
Wheelbase of each bogie	1·520
Length of the car body	11·400

The car has a luggage compartment in the centre, directly above the engine. Only the cylinders of the engine project above the floor of the compartment. Seating accommodation is provided for 42 passengers. The total weight of the car is 21·5 tons, of which 7 tons is due to the petrol-electric equipment. When running without a trailer a speed of 80 km. per hour was reached on the level, and with a 16-ton trailer a speed of 70 km. per hour.

GENERAL CONSIDERATIONS.

The Adoption of Motor-vehicles.—The advantages of independent motor-vehicles, no matter of what type, whether steam, accumulator, petrol with mechanical transmission, or petrol-electric, depend essentially on the possibility of forming trains of less weight, and consequently of employing a greater number of trains than is the case with steam locomotives. This increase in the number and frequency of the trains should result, in general, in an increase in traffic, and consequently in the revenue, which would cover—supposing that the working expenses, viz., the cost of fuel and maintenance, are not too high—the initial capital outlay of certain secondary or local lines which, if operated with steam locomotives, could not give such good results.

This use of independent motor-vehicles could even be extended to certain main lines of important railway systems, and would allow an increase in the actual overall speed of long-distance trains, by doing away with stops at the less important stations, such stations being served with independent motor-trains. This method of working, viz., separating the general traffic from the local traffic, would make it possible to do justice to the requirements of these two kinds of traffic, which requirements are at present so conflicting; and in that way it would bring about an increase in the speed and frequency of communication, both of which are so much insisted upon by the travelling public.

The Use of Petrol-electric Motor-vehicles.—The introduction of petrol-electric cars has numerous advantages. By using internal-combustion engines the car is always ready to start, and only a short time is required to take in fuel, &c., for long journeys. The starting is as rapid as in the case of all vehicles adapted for electric traction, consequently the net speed is increased. One man only is required to drive the car, which is easy and safe to work. The driver, having neither a fire to look after nor a pump or injector to attend to, can concentrate all his attention on the speed of the car, and on the track and the signals. The absence of smoke, and the fact that he stands at the front of the car, facilitate his observation of signals, &c.

The petrol-electric cars are very flexible as regards their operation, owing to the system of control employed. If the stops are of long duration the engine can be shut down and any waste of fuel thus avoided. The cylinders of the internal combustion engine can be water cooled, which could not be done in the case of steam cars. The maintenance of petrol-electric cars can be attended to without interrupting the service, whilst the maintenance of locomotives and steam cars requires their removal from service for the frequent cleaning of the boilers. Repairs are rarely necessary to well-cared-for cars, and the removal from service for this purpose is consequently of short duration, the parts to be repaired or replaced being of comparatively small weight. The use of petrol electric vehicles, moreover, cannot result in the burning of vegetation bordering the track, which often happens in the case of locomotives and steam cars due to the scattering of sparks.

The use of two driver's cabins dispenses with the necessity of turning the car at the terminus, and consequently with turning-tables, loops, or reversing triangles. The reduced weight of the petrol-electric cars and their smooth running reduce the wear of the rails to a minimum. Petrol-electric cars with electric motors are capable of working either from overhead wires or from a third rail on railway sections equipped for electrical working. On other sections of the track the cars work by means of their own electric generating plant. The petrol-electric cars with electric motors can be coupled together by very simple contrivances to form trains which can be operated from one of the driver's cabins, as is done in the case of multiple-unit electric traction.

Finally, it must be pointed out that the petrol-electric car having no permanent mechanical connection between the engine and the axles may be placed between any two carriages of a train hauled by a steam locomotive, and may be used as an ordinary carriage. At any point en route the petrol-electric car may then be removed and continue its journey in any desired direction by its own means of propulsion. In this way several distinct trains may be combined as one train, each section branching off as required.

The principal disadvantage of the petrol-electric car, and one not to be overlooked, consists in the danger of fire, consequent on the use of a highly inflammable liquid fuel. However, this danger can be completely overcome as follows: (*a*) By using a car entirely constructed of steel and with a concrete floor. (*b*) By enclosing the engine in a compartment with a duplicate iron-sheet partition, the space between the two sheets being filled with fire-proof composition. (*c*) By automatic admission of the fuel to the engine, the supply being interrupted in the case of fire. (*d*) By keeping the liquid fuel in a reservoir under an inert gas, and not in contact with the air. (*e*) By storing the fuel with an inert gas under pressure.

As to the seemingly complicated structure of the car, it must be pointed out that the component parts are very simple, and the most complicated part, the internal-combustion engine, has been so extensively adopted that this point need not be discussed.

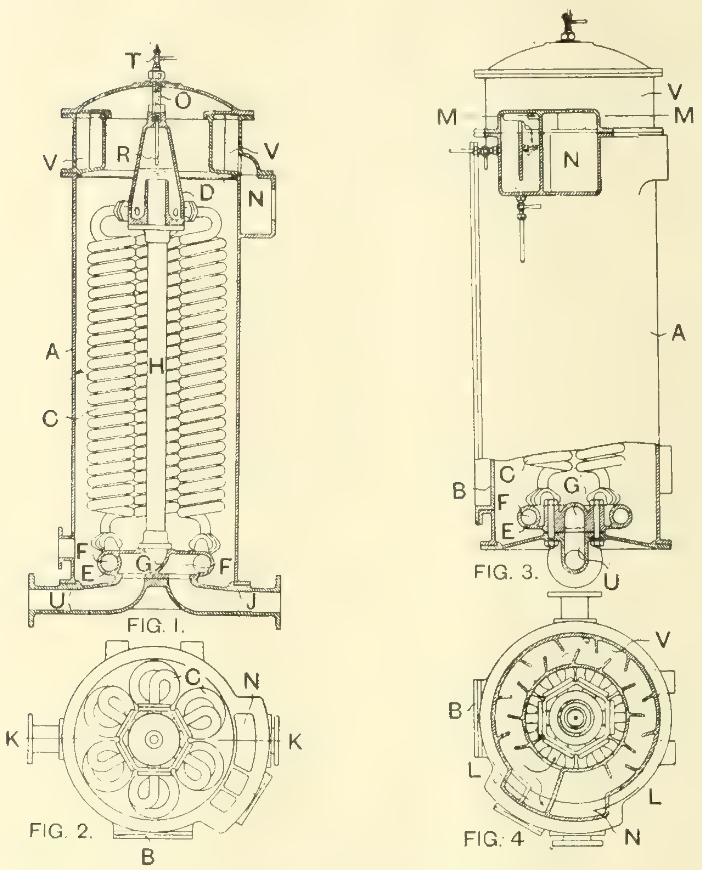
(To be continued.)

MORISON'S FEED WATER HEATER.

WE illustrate herewith a construction of tubular surface feed-water heater, the invention of Mr. D. B. Morison, of Hartlepool Engine Works, Hartlepool. In this design improved facilities are, it is claimed, afforded for the separation of air and oil from the feed water, and for the easy examination, cleaning, jointing, withdrawal and replacement of the coils. Fig. 1 is a sectional elevation on line K in Fig. 2. Fig. 2 is a plan view with the upper portion of the apparatus removed. Fig. 3 is a side elevation showing at the top of the apparatus a section on the line L in Fig. 4; and at the bottom a section showing the water outlet from the heating coils; and Fig. 4 a sectional plan view on the line M in Fig. 3.

The heating vessel A is cylindrical and vertical and is provided with a door B at the side for the removal of the coils. Arranged in the interior are multiple tubular coils C,

vertically disposed between two water receivers D and E to which they are connected at the top and bottom, the receiver E containing a circumferential inlet passage F and a central outlet passage G for the feed water which flows from the inlet passage F upwardly through the coils C into the top receiver D from whence it passes down the central pipe H into the outlet passage G, the central pipe H forming a support for the top receiver D. The water inlet F and outlet G are in communication with corresponding water inlet and outlet passages U J formed in the base of the apparatus to which the bottom receiver E is connected by flanged joints and bolts, the bolts extending through the base of the heating vessel with the nuts outside. The top receiver D has attached to it a lifting device O which extends through the cover of the heating vessel with suitable provision for expansion and is fitted by a nut, so that by disconnecting the bottom receiver E from the base both the receivers and their connections may be raised vertically whereby any one of the coils C can be rotated



MORISON'S FEED-WATER HEATER.

and brought opposite the door B for inspection, cleaning, or removal. The top receiver D is extended upwardly in the form of a cone which forms a separating chamber for the collection of air, and it may be oil, from the heated water which enters the receiver D and is caused to flow in an upward direction so that the stream of water travels to the water level in the receiver and thus promotes the separation of air and oil which accumulate in the upper portion of the receiver and may be discharged continuously or periodically through a central pipe R and control cock T. The pipe R extends downwardly into the cone, in order to maintain a quantity of air in the upper portion of the cone so as to provide a water surface for the liberation of air and the collection of oil, the entrapped air also forming a cushion for the water discharged from the coils. The steam supply pipe may be connected to the chamber N and the steam passed through a cleansing chamber V before entering the heating vessel A. Or if desired this chamber may be omitted and the steam supplied direct to the heating vessel A. The heater is provided with the usual stop valves, safety valves, cocks, gauges and other mountings and requirements necessary for the satisfactory working of the apparatus.

Boiler Explosion at Hawksworth.—The formal investigation ordered by the Board of Trade to be held in regard to the boiler explosion at Gaping Goose Farm, Hawksworth, is fixed for hearing in the Town Hall, Guiseley, Yorkshire, on Wednesday, July 2nd, at 11 a.m.

THE ILLMER TWO-STROKE CYCLE GAS ENGINE.

THE first gas engine of American origin to employ the double-acting, 2-stroke cycle has recently been constructed by the Reading Iron Company from the designs of Louis Illmer, jun. It is shown in the accompanying illustrations, for which, along with the following particulars, we are indebted to our American contemporary, "Power."

The engine is of the slow-speed type, designed for heavy-duty service along the lines of steam-engine practice, and the aim throughout has been to reduce to a minimum the number of working parts. In carrying out this idea a number of unusual features have been embodied. In the first place, all previous applications of the double-acting, 2-stroke cycle have employed separate air and gas pumps. In the Illmer engine, however, this work is accomplished by a single pump of the double-acting type, the stratification principle being employed in scavenging and in the admission of the charge.

A second mark of individuality is the valve gear, which is a distinct departure from usual practice. This is positively actuated by means of an eccentric drive, the inlet valves being opened and closed by a double-toggle linkage, as shown in Fig. 1; there is a total absence of springs, except for the small ones on the igniters. In this way properly accelerated and retarded movements are imparted to the valves and cause them to seat gently, the valves being pressed on their seats by a slight springing of the rocker shaft. Provision is made for independent adjustment by having all the link pins bronze bushed and the links provided with keepers to allow for wear. The pump valves are actuated direct from the wristplate. As the engine is of the 2-stroke cycle type, there are, of course, no exhaust valves.

The inlet valves are of the annular poppet type, coaxial with the cylinder, and that on the crank end surrounds the piston rod (see Fig. 2). They slide in housings, and suitable packing is provided. This arrangement permits a large inlet port opening into the power cylinder (about 25 per cent. of the piston area) and thus tends to reduce the pump work, which is said not to exceed 5 per cent. of the indicated power of the engine.

Replaceable liner sections are fitted to the power cylinder, and the exhaust ports, drilled into the inner liner ends, are surrounded by an annular exhaust chamber cast integral with the cylinder. A handhole in the exhaust chamber admits of cleaning the exhaust ports and also provides a means for inspecting the piston rings. The engine is of the side-crank type, a drag crank being provided for driving the pump piston and the governor.

Fig. 2 is a section through the power cylinder, inlet valves, pump cylinder and ducts representing that position in which the air and gas are being drawn into the pump on the head end (right) and the charge forced into the working cylinder on the crank end (left). Following through the pump cycle, first consider only the head end with the pump piston just beginning its travel toward the left. The valve V would then be rotating counter-clockwise, so as to uncover the ports A and D, B and C already being open. This permits air to be sucked through A and B; also, residual air from the previous charge, which has remained in the upper part of duct F, is drawn into the pump cylinder through passage G. The latter creates a suction in duct F, and draws in gas through ports C and D, the height to which the gas rises in F depending upon the governor, which controls the throttle valve T. The air lying behind the inlet valve in the pocket I is not displaced by the suction of the pump, but remains in this position during the entire period of inlet closure to be introduced into the power cylinder as scavenging air ahead of the next charge. The relative positions of the air and gas when the pump piston has just passed mid-travel on the suction stroke, are indicated in the sketch (head end).

By the time the pump piston has reached the end of its stroke, the valve V will have rotated in a clockwise direction so as to close ports A and D and start to open port E. During the first part of the return or discharge stroke the charge is compressed slightly. Just previous to the pump piston reach-

ing mid-stroke the power piston uncovers the exhaust ports and simultaneously the inlet valve opens. Port E is now entirely uncovered, and a free passage is established between the pump cylinder and the lower end of duct F. Hence part of the air is forced through ports B and E, pushing the column of gas ahead of it, and at the same time the rest of the air is forced through passage G, around F, and meets the gas at the mixing ports H.

The residual air in the pocket I and any air ahead of the body of gas will have been forced ahead of the mixture to scavenge the cylinder of burnt gases. The crank-end view of Fig. 2 represents the position taken by the mixture charge at the instant of entering the power cylinder. When the inlet valve closes, the mixture will have been forced into the power cylinder, and the air lying behind it serves as scavenging air for the next charge.

A by-pass (not shown) connects the two ends of the pump. By setting the valve in this the air may be so regulated as to control the position of the mixture within the power cylinder. The air-check valve (not shown) in the passages G and G′ opens inward so as to provide a free passage of air toward the pump. On the discharge stroke of the pump the check closes and the air has to pass around the valve, the opening being made adjustable by the setting of a lever. Accordingly a relatively large body of gas may be sucked into the duct F without being affected perceptibly by any throttling adjustment made for the air discharge through the connections G or G′, whereby to adjust the ratio of air to gas in the mixture charge. The purpose of the walls J and J′ is to form pockets, which cause the air to eddy and spread before discharging into the neck of the ducts.

An important feature of the power-cylinder design are the lugs of baffles K and K′. The charge enters the cylinder in the form of a hollow cone around the inlet valve, and strikes the baffle K or K′ approximately normal to its direction of flow. This causes the mixture to whirl and lose much of its velocity, spreading over the cylinder and driving out the scavenging air. Proper spreading of the charge is largely facilitated by a new principle embodied in the cylinder-head construction, namely, the turning of the working charge and imparting to it a direction of flow parallel to the power cylinder axis before discharging it through the inlet port.

The engine shown in the illustration is rated at 300 h.p., and has for some time been carrying the entire shop load of the Scott Foundry Department of the Reading Iron Company. It operates on producer gas. A similar one of 500 h.p. is nearing completion. Fig. 3 is a reproduction of an indicator diagram taken under operating condition, and Fig. 4 shows an indicator diagram taken from the pump.

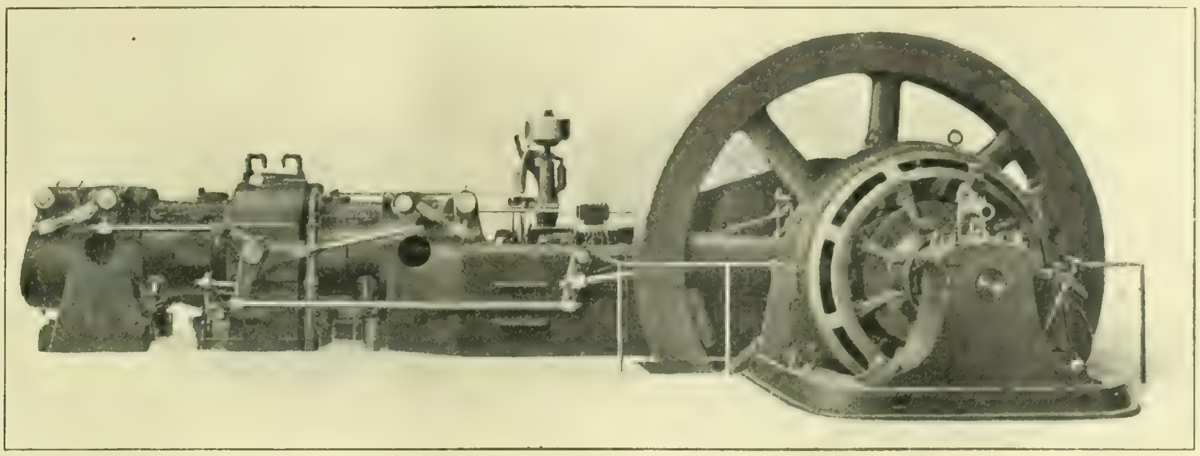


FIG. 1. ILLMER TWO-STROKE CYCLE GAS ENGINE.

In the following table are given the results of a 33½-hour full-load test on this engine:—

TEST OF 300 H.P. ILLMER GAS ENGINE.

Duration of test, hr.	33½
Grade of coal...Westmoreland bituminous @ 14,100 B.T.U. per pound as used	
Character of load	Water rheostat
Average load registered on calibrated recording ammeter, ampere	774
Average voltage (corrected)	253
Average developed load, kw.	196
Average developed load, b.h.p.	284
Power required for auxiliaries, kw.	11
Power required for auxiliaries, b.h.p	16

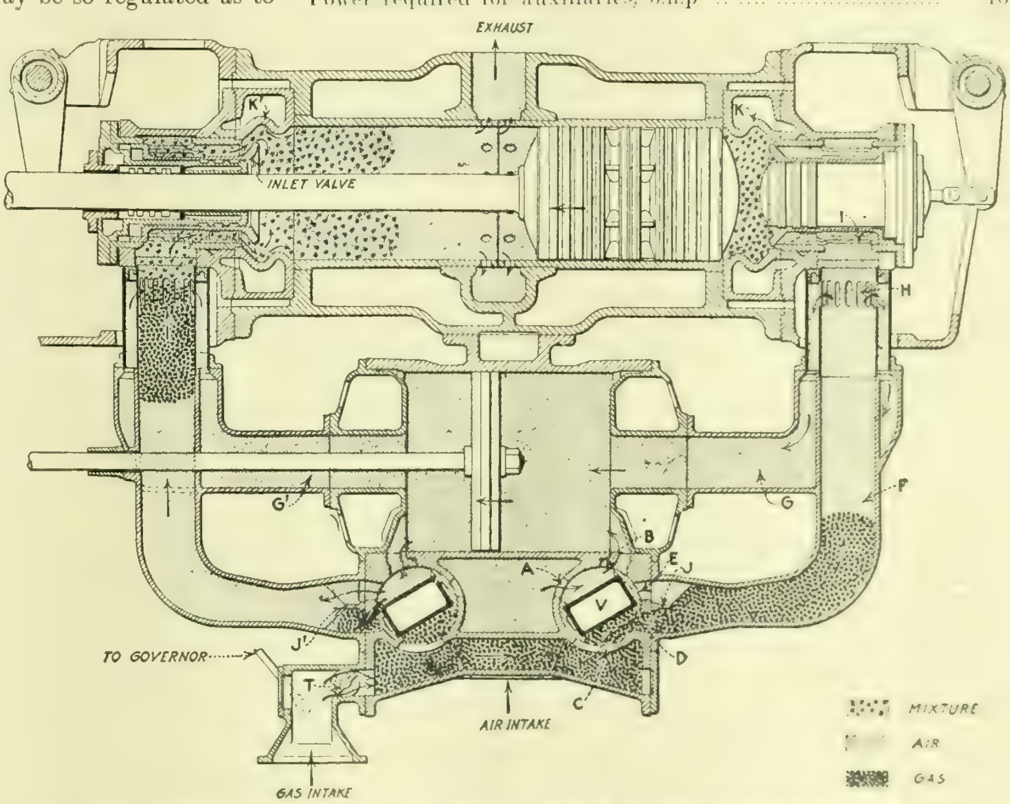


FIG 2.—ILLMER TWO-STROKE CYCLE GAS ENGINE. SECTION THROUGH CYLINDER AND PUMP. ILLUSTRATING STRATIFICATION OF CHARGE.

COAL BURNED—

Fed to hopper, lb.	10,352
Equivalent required for steam jet blower, lb.	502
Total coal used in 33½ hr., lb.	10,854
Cold cleaned gas measured in holder, feet per pound of total coal used	65.4

ANALYSIS OF GAS—

CO_2	2·91	per cent. by volume.
O_2	0·2	per cent. by volume.
C_2H_4	0·7	per cent. by volume.
CO	27·51	per cent. by volume.
H_2	6·52	per cent. by volume.
CH_4	2·21	per cent. by volume.

Average B.T.U. of gas by calorimeter (35 determinations corrected for holder temperature, and pressure) B.T.U. per foot higher	144
Average B.T.U. of gas by calorimeter (35 determinations corrected for holder temperature, and pressure) B.T.U. per foot lower	138
Producer efficiency on basis of cold cleaned gas and total coal used, per cent. on higher B.T.U. of gas	67

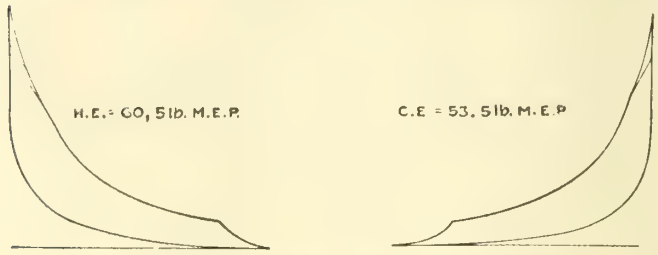


FIG. 3. POWER INDICATOR DIAGRAMS FROM CYLINDER.

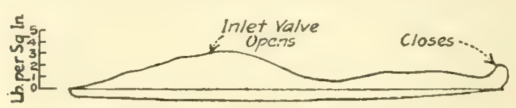


FIG. 4. INDICATOR DIAGRAM FROM PUMP.

Producer efficiency on basis of cold cleaned gas and total coal used, per cent. on lower B.T.U. of gas	64
Thermal efficiency of engine, lower B.T.U. per b.h.p. hour	10,300
Total coal used per developed b.h.p. hour, lb.	1·14
Total coal used per developed kw. hour, lb.	1·65
Total coal used per b.h.p. hour, delivered for use, lb.	1·21
Total coal used per kw. hour, delivered for use, lb.	1·75

The instruments on which the results were obtained have been checked with the general electric standards, and it was found that the instruments read a little low; hence the revised results are even more favourable than the original figures.

INSTITUTE OF MARINE ENGINEERS.

ON Saturday, June 7th, a visit of inspection was paid by a party of members cf the Institue of Marine Enigneers to the paint and varnish works of Messrs. R. Gay & Co., Ltd., and Robt. Ingham, Clark, & Co., Ltd., Stratford.

The firm of Robt. Ingham, Clark, & Co., Ltd., enjoys a high reputation for the quality of varnish produced, and it was this part of the works which proved of especial interest. It consists of about 25 buildings of moderate dimensions, so constructed that the windows of one building do not face those of another. This formation is adopted in order that any building may be readily isolated in case of fire, and a very efficient and well-equipped works fire brigade is a further precaution against such an event. Previous to the inspection of the works, the visitors were shown various specimens of the fossilised gum which forms the basis of the varnish. These gums are in a fossil form up to 2,000 and 3,000 years old, and require a temperature of about 600° Fah. to melt. After visiting the gum stores, containing supplies of varying qualities and colours, the running or boiling room was inspected. Large copper cauldrons containing the gum are placed over sunken fires at a high temperature. About 25 per cent. of the material is given off in fumes, which are drawn through pipes by means of electrically-driven fans. These fumes are condensed, and the residue sold for commercial purposes. The remaining liquid, after a process of filtering and straining, is conveyed to the maturing warehouses, which have a total tank capacity of 500,000 galls., where it is left for a period of from 9 to 12 months to settle and mature. The total output of varnish from the factory is about 500,000 galls. per annum, and of this a large quantity is exported, the colonial and continental warehouses showing the extent of the business done, apart from the home trade. The manufacture of the "Pearline" enamel was then shown, the mixing, grinding, and other machines being electrically operated. The preparation of linseed oil was also a process which excited much interest.

The paint factory of Messrs. R. Gay & Co., Ltd., in which about 250,000 galls. are produced annually, was next visited, and an opportunity was given of seeing the various processes of manufacture. A speciality in this department is the orange red lead made by the firm, which, in addition to having special preservative qualities, retains its original colour for long periods under exposure to the weather. The firm also specialise in the manufacture of zinc white paint for decorative purposes, and this also was shown in process of manufacture. In the handsome exhibition room were seen beautiful specimens of the work accomplished with materials manufactured by the firm, also specimens of the raw materials, &c.

A vote of thanks to the company, and to Mr. R. S. Clark, Mr. T. W. Bamford, and other gentlemen, under whose guidance the visit was made, was heartily accorded, on the proposal of Mr. Jas. Adamson (hon. secretary), seconded by Mr. Jas. Shanks.

In the evening the members, through the courtesy of the General Steam Navigation Company, paid a visit of inspection to the company's steamer "Fauvette," at present engaged in the London-Bordeaux service. The vessel, which is the latest addition to the company's fleet, has been constructed and fitted throughout on a generous scale, and with commendable forethought for the comfort of passengers and the expeditious handling of cargo. At the conclusion of the visit a vote of thanks was heartily accorded to the company, on the proposal of Mr. W. T. Seaton, seconded by Mr. A. H. Mather, also to Mr. G. L. Florence, engineer-in-chief to the company, under whose guidance the inspection was made.

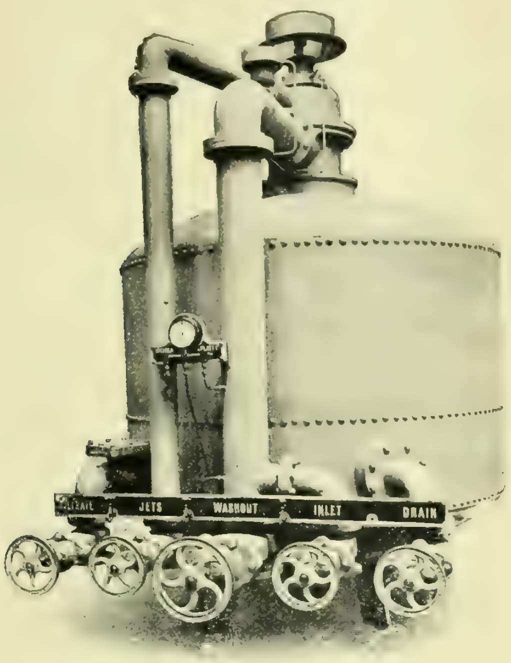
GOVERNMENT COMPETITION FOR AEROPLANE ENGINES.

THE War Office have issued particulars of a naval and military aeroplane engine competition, which will begin at the Royal Aircraft Factory, Farnborough, on February 1st next year. A prize of £5,000 will be awarded to the maker of the engine which in the opinion of the judges best fulfils the stipulated requirements and which is entirely suited for adoption for the aeroplane service. Orders up to the value of £40,000 will be given. Competitors who enter engines up to the number of 10 which do not win prizes but which are useful will receive £100 in respect of each engine. Engines of British manufacture throughout are specified, with a horse-power of 90 to 200, with more than four cylinders, and weighing not more than 11lbs. per horse-power. Desirable qualities are light weight, economy of consumption, absence of vibration, smooth running, slow running, silence, absence of deterioration, simplicity, suitability to head resistance, precautions against accidental stoppage, accessibility, adaptability for starting, freedom from risk of fire, absence of smoke or ejections of oil or petrol, convenience of fitting, relative invulnerability to small arm projectiles, economy of space, part equipment, excellence of material and workmanship, reasonability of price, and satisfactory running under climatic variations. The tests will include two runs of six hours each at full power on throttle down, and short special runs in inclined positions not exceeding 15°. Entries will be received up to August 1st this year, and the engines are to be delivered at the factory by January 15th next.

Pit Cage Accidents.—Twelve men were descending the Langtree Pit, Standish, in the cage on Saturday last, when there was a violent collision between that and the ascending cage. Four men were badly injured, two sustaining fractured legs. A fatal accident occurred in No. 7 shaft, Capringstone Pit, near Dreghorn, on Sunday last. Some repairs were being carried out in the shaft, and two young men were in a cage in the shaft when something went wrong with the machinery, and the cage was dashed to the bottom of the shaft, a distance of over 100ft. One of the men was killed instantaneously, and the other was seriously injured.

WATER PURIFICATION.

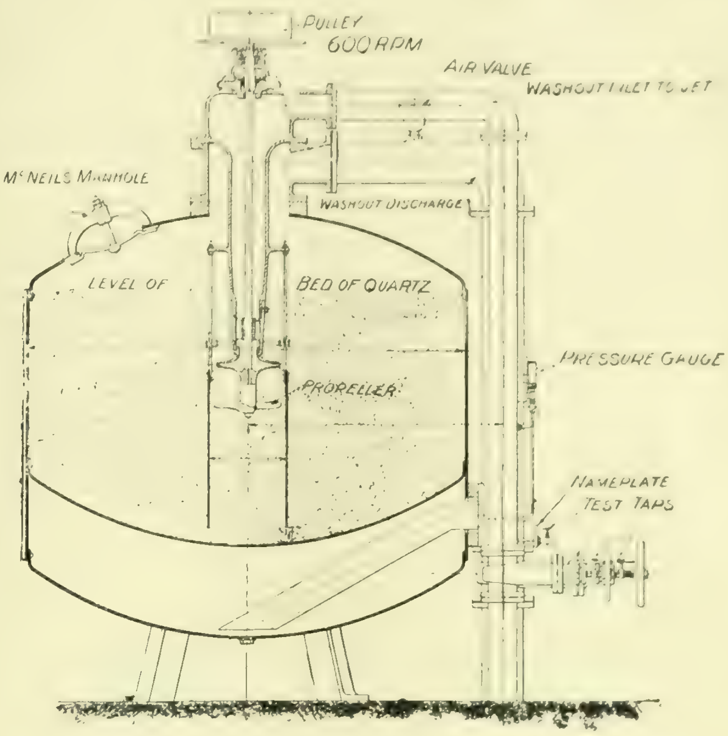
The filtration and purification of water for public or industrial purposes is a subject to which the firm of Messrs. Mather and Platt, Ltd., of Manchester, have devoted considerable attention, and for which they possess special facilities. In the early stages of the development of mechanical filters, they devoted special attention to the design of chemical apparatus, and they have placed on the market several types, suitable for different working conditions. The advantages of such apparatus are greatest when the water to be dealt with is discoloured or contains finely divided matter in suspension, and it is necessary to adopt some form of chemical treatment prior to filtration, by which the water so treated is rendered bright and clear, perfectly free from suspended matter and colour, and the bacteriological purity obtained is nearly 100 per cent.



General View of Agitator-type Pressure Filter with Piping and Valves.

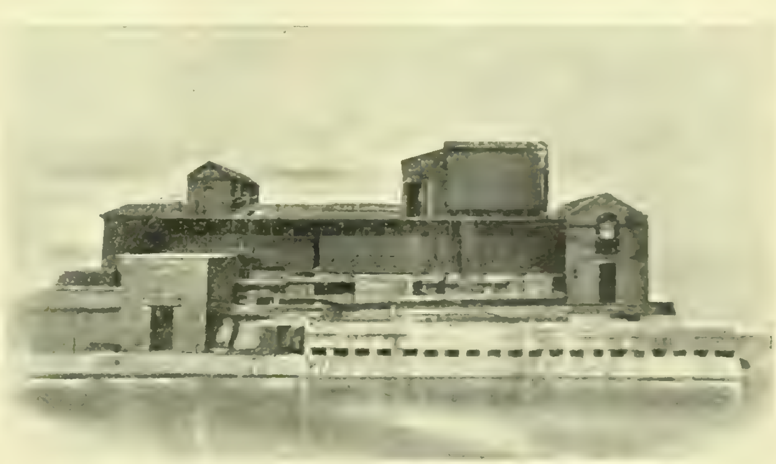
The special feature of the filters is the washing device, which consists of a central vertical tube fixed in the centre of the filtering bed of quartz crystals, extending upwards to within a few inches of the top level of the filtering material. Suspended in the tube is the steel shaft, on which are fixed a short distance above the top of the tube two jets connected with the filtrate main, and blades in the form of a propeller situated in the upper end of the tube. The shaft is driven from outside the filter, and after the bed is suspended by an upward flow, the shaft is revolved at a high speed, causing the contents of the bed to be brought by the propeller through the tube, where the quartz is cleansed by clean water issuing at a high velocity from the jets. When the shaft is stopped, the quartz slowly sinks to the bottom, and the impurities are carried away with the wash water through the discharge pipe at the top of the filter. With this arrangement the whole bed is absolutely scoured, and the filter gives better results which last for a longer period before it is again necessary to wash out. This is of paramount importance in municipal work, where it is essential that the water supply should be as pure as it is possible to make it.

Messrs. Mather & Platt, Ltd., recently completed a large contract for the Sheffield Corporation comprising 32 pressure filters, each 8ft. diam., for dealing with the Loxley Valley water supply. The results were so satisfactory that a repeat order has been placed for a further 24 filters to deal with the Derwent supply. Another large contract recently completed was for the Ashton-under-Lyne, Stalybridge, and Dukinfield Waterworks. The contract comprised 33 filters, each 8ft. diam., divided into two installations. Some months ago a small installation was put down for the Fraserborough Town Council, and again with such satisfactory results that a repeat order has been given for an extension of the plant. All the foregoing installations were for filters fitted with the special chemical apparatus and the improved washing device previously described. The firm also have in hand at the present time a contract for a complete plant of special design for dealing with the water supply to a rubber estate in the Malay States.



Sectional View of 8ft. Diameter Filter.

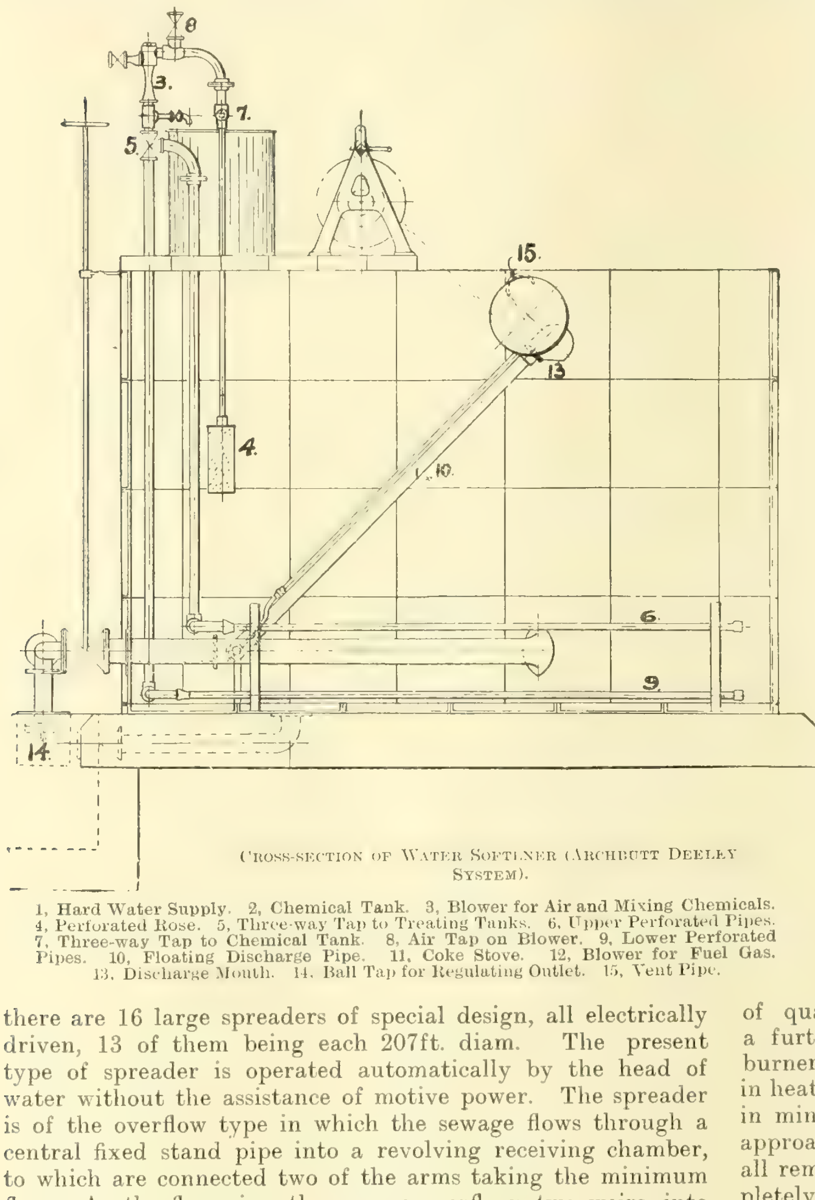
Messrs. Mather & Platt, Ltd., have also carried out some very important contracts for water softening. They were, indeed, the pioneers of water softening on a mechanical scale, as they were the sole licensees for the Archbutt Deeley type of plant, which is so largely adopted by waterworks in Great Britain where the supply is considered too hard for domestic purposes. By the Archbutt system the impurities are quickly precipitated and settled, thus reducing the actual first cost and ensuring a saving of chemicals, as well as more satisfactory purification. The plant consists of two cast-iron tanks capable of treating 600 to 10,000 gallons per hour, according to size. For more than 10,000 gallons per hour three or more tanks are used. The main feature of the apparatus is that the whole water supply is held under complete control. Each



Water-softening Plant at the Willesden Works of the Metropolitan Electric Supply Company, Ltd.

tankful is treated separately, so that any imperfections in the treatment can be rectified before the water is turned on to the mains. This is impossible with the continuous type of water-softener, as in that case imperfections in treatment cannot be ascertained until the water has passed through the softener. A large installation carried out at the Ilkeston and Heanor Waterworks, Matlock, has been giving exceedingly good results. It comprises a plant capable of dealing with nearly 2½ millions per day. An installation at Swadlincote and Ashby Waterworks, near Burton-on-Trent, dealing with over a million gallons per day, is likewise giving most satisfactory results.

For the manufacture and installation of sewage works, Messrs. Mather & Platt, Ltd., are also well known, and many of the largest sewage works in England are equipped with their spreaders. At Huddersfield Corporation Sewage Works



CROSS-SECTION OF WATER SOFTENER (ARCHBUTT DEELEY SYSTEM).

1, Hard Water Supply. 2, Chemical Tank. 3, Blower for Air and Mixing Chemicals. 4, Perforated Rose. 5, Three-way Tap to Treating Tanks. 6, Upper Perforated Pipes. 7, Three-way Tap to Chemical Tank. 8, Air Tap on Blower. 9, Lower Perforated Pipes. 10, Floating Discharge Pipe. 11, Coke Stove. 12, Blower for Fuel Gas. 13, Discharge Mouth. 14, Ball Tap for Regulating Outlet. 15, Vent Pipe.

there are 16 large spreaders of special design, all electrically driven, 13 of them being each 207ft. diam. The present type of spreader is operated automatically by the head of water without the assistance of motive power. The spreader is of the overflow type in which the sewage flows through a central fixed stand pipe into a revolving receiving chamber, to which are connected two of the arms taking the minimum flow. As the flow rises the sewage overflows two weirs, into special pockets, to which are attached the two arms which take the maximum flow. By this means joints or seals are unnecessary. Amongst the municipalities equipped with spreaders of this type are Rugby, Melton Mowbray, Keighley, Haslingden, Rawtenstall, &c., while the firm have at present in hand a large contract for spreaders, together with pumps and electrical equipment, for the Accrington and District Sewage Board.

Fatal Boiler Explosion on a Steamer.—While the American lake steamer "E. M. Peck" was discharging her cargo of coal at Racine a few days ago, the starboard boiler burst. Five men were killed and six injured. The steamer took fire, and the fire was not extinguished until much damage was done.

NOTES ON "GASEOUS HEATING."*

BY E. W. SMITH AND C. M. WALTER.

Illuminating Power v. Calorific Value. — The illuminating power of town gas is rapidly becoming of less and less importance, and the calorific value has assumed the premier position. With the rapidly-increasing use of incandescent lighting, even illumination no longer depends on the candle power of the naked flame. Perhaps a useful purpose will be served if we ask you to review, briefly, what quality of gas is best suited for use in heating processes. It will be agreed at the outset that it is of much more importance that the quality of the gas should be fairly constant, whatever it is, than that it should be high. If the calorific value be high and very irregular, less satisfaction will be given to the consumer than if the calorific value be much lower but more constant. A satisfactory gas for a town gas is one averaging 520 B.Th.U. net, and not varying by more than 3 per cent., or 15 B.Th.U. either way.

With modern plant and proper supervision, where only coals of the same class are used, there should be little difficulty in attaining this standard, it being a much easier one to work to than the present illuminating power standard. But evenness in calorific value is not the only factor to be taken into account Where water gas is employed for enrichment purposes naturally it is only used when enrichment is necessary. Its high specific gravity and high calorific value will have a tendency to make the town gas streaky, varying considerably in calorific value and also in specific gravity. This latter should not be allowed to vary too much, as the volume of gas passing through the jets of the apparatus in which the gas is being burnt will vary inversely as the square root of the specific gravity of the gas. With high-density gas, less gas will be burnt than with low-density gas, and consequently less heat be generated and temperatures will drop. The effect of increase in density is equivalent, in furnace working, to a drop in the calorific value of the gas. For example, it is not an unheard-of thing in bad cases for a specific gravity to vary from ·45 to ·60 on town gas. This would mean that the amount of gas passing through a given jet, passing 100 cub. ft. an hour at ·45, will decrease to 86·5 at ·6.

$$\frac{100}{1} \times \sqrt{\frac{\cdot 45}{\cdot 6}} = 86{\cdot}5$$

Most frequently high specific gravity is accompanied by higher calorific value, a ·6 gas in all probability having a calorific value of 600 B.Th.U., or an increase of 12 per cent. Serious variations of quality — calorific value and density — will produce a further difficulty; the aëration of the mixtures in the burners will vary too. These are all controllable factors in heating efficiencies; but they none the less have to be borne in mind and carefully watched. We believe we are rapidly approaching the time when, although the sulphur clauses be all removed, it will be necessary for gas undertakings to completely abstract the sulphur compounds contained in the gas. This is as necessary for lighting gas as for heating gas. When the carbonic acid and sulphuretted hydrogen of coal gas are extracted with ammonia, very little difficulty will arise in removing the sulphur compounds by means of sulphided lime. The quantity of gas used in a furnace will also vary with the barometric pressure and the temperature of the gas. It is possible to get extremes of 28in. and 30in. barometric pressure. In such a case the number of B.Th.U. passing per hour would be 6·7 per cent. more at the higher pressure than the former. A difference in temperature of 15° Fah. is not exceptional. This would make a difference of 3 per cent. It must be remembered, however, that these variations never occur at once all in the same direction, they usually having a nullifying effect one on the other.

* Abstract of paper read before the Institution of Gas Engineers, June, 1913.

Constant Pressure Essential.—Constant pressures at the furnace jets are perhaps as important as unvarying quality. The only difficulty that arises is as to the best means of maintaining constant pressures at the consumers' jets. Some prefer governors at each furnace, others one governor at the meter. In the latter case, especially in low-pressure installations, it is necessary that the supply pipes should be well above the capacity of the work they are called upon, or are likely to be called upon, to do.

Assuming that a correct gas is being supplied in an efficient way, what is the best way of burning that gas to give the best results and highest efficiencies? When gas of known composition is burnt completely, a certain quantity of heat is generated. However it may be burnt, the amount of heat so generated is invariable. It may be burnt so slowly that the products are not raised more than a few degrees, and it may be burnt at such a rate that the temperature of the flame reaches well over 2,000° C. The total heat evolved is the same in either case.

For the purpose of this discussion of the subject, it may be said that the methods of heating may be divided into two classes: (1) Direct heating from flames by means of such appliances as ring and bar burners. (2) Indirect heating, as in the instances in which the gas is burnt in contact with refractory material, which is raised to a high temperature and radiates its heat on to the object it is primarily desired to raise in temperature. All muffle and oven furnaces are of this type.

The effects to be obtained in each of these processes can be varied almost to infinity. In the first method, more especially, heating efficiences depend very largely on the temperatures attained in the flames. It has been well pointed out by Prof. Dalby, in his paper on "Heat Transmission," how high initial temperatures affect heating results. As an illustration, he examines the heat changes that take place in the firebox of a steam boiler, and traces the drop in head of heat in its transmission from one medium to another. The combusting gases in the firebox have a temperature of over 1,000° C. These give up their heat to the film of non-circulating gas found on the surface of the boiler plate at an average thickness of $\frac{1}{40}$th of an inch. The heat has then to be transferred to the scale on the plate, through the scale, from the scale to the plate, through the plate, from the plate, through any scale or grease that may line the inside of the boiler, to the film of non-circulating water, and from this film to the main bulk of the water.

Each stage in the transmission reduces the initial head of heat—say, 1,000° C.—until a temperature of about 100° C. is attained in the water. It is shown that well over 90 per cent. of this head of heat is lost in its transference through the thin gas film on the firebox side of the boiler plate. As is to be expected, the better and more rapid the circulation of the gases in the firebox the thinner will be this gas film, and the less will be the drop in temperature head. The higher the initial temperature is, the higher will be the final temperature of the containing box and the quicker will be the flow of heat. This all has a very important bearing on the results to be obtained in gaseous heating by means of naked flames. It may safely be assumed that no more than 10 per cent. of the heat generated in the flames of industrial ring burners is radiated, and little more than half this will be radiated in a useful direction. Consequently, the heating will have to depend very largely on the actual contact of the hot gases—completely combusted and partly combusted—with the vessel to be heated. Here we have similar conditions to those present in the experiments described by Prof. Dalby.

Some time ago we were asked what we should suggest as the most efficient apparatus in which to melt, and maintain at a given temperature, large bodies of white metal. Two important points had first to be settled. Firstly, what in this instance would be the best way of applying the gas to the pots; and, secondly, what shape of pot would give the best results. Let us take the second of these points first. When considering the melting of such metals, it will be evident that the fuel costs will to a great extent depend on the quantity which has to be dealt with at one time in relation to the shape of the pot. For example, if we compare a bowl shaped pot, the internal diameter of which is, say, one unit, with another pot, the internal diameter of which is (say) 2 units, then the capacity of the latter pot will be approximately eight times that of the former, while the heating surfaces of the two pots are approximately in the ratio of 1 : 4. This means that the heating surface of the larger pot per pound of metal contained in it is only half that in the case of the smaller pot. This explains why the cost of melting such metals in bowl shaped or conical pots increases as the quantity to be dealt with increases. The converse, however, also holds good; and if we consider the cooling effect on the metal we have, neglecting the surface effects—the smaller pot losing heat at twice the rate of the larger pot—thus the cost of maintaining the metal in the molten state will be much less in the case of the larger pot than in the case of the former pot. It will thus be seen that the shape of the pot adopted will to a large extent affect both the melting and maintaining costs.

Fig. 1 represents a section through a lead melting pot setting heated by means of a high-pressure gas chamber burner (Fig. 2). It will be seen that the combustion space C (Fig. 1) is shaped to the pot P, the space between the pot

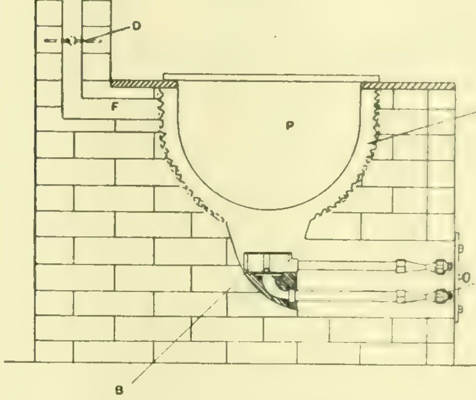


FIG. 1.—SECTION THROUGH MELTING POT SETTING.

itself and the furnace wall not exceeding $2\frac{1}{2}$in. in the case of the largest pots, having a capacity of upwards of 2 tons. The high-pressure duplex burner is fitted with injectors I (Fig. 2), the burner chamber being closed by a door having an opening left in it for the admission of secondary air. The flue outlet F (Fig. 1) is placed at the back as near to the rim of the pot as possible, and should take the shape of a horizontal slit having a height not exceeding 2in., the width being arranged according to the amount of gas burnt. The main flue should also be fitted with a damper D.

The firebrick wall of the setting should be rough-cast with broken firebrick and ganister, so as to expose to the flames as large a heating surface as possible. If conical pots are used, these should preferably be made of close grained cast iron, having a minimum thickness of $\frac{3}{4}$in. in the case of small pots and 2in. in the case of the larger pots. Wrought-iron pots of this type have been tried, but owing to their short life they have had to be abandoned.

Fig. 3 represents a bath-shaped pot composed of $\frac{1}{2}$in. wrought-iron plate with the ends welded in, which was designed with a view to obtaining a greater heating surface as compared with that of a conical pot of the same capacity. A pot of this type having dimensions 27in. by 27in. by 24in. deep was constructed for the melting of a solder composed of lead and tin in equal proportions. Two single burners were fitted, each having a consumption of about 225 cub. ft. per hour, the gas being supplied at a pressure of $11\frac{1}{4}$lbs. per square inch. With the setting heated up, it was found that 35 cwt. of such metal could be reduced to a molten state and raised to a temperature of 650° Fah. in one hour 35 minutes, the gas rate during this period being 450 cub. ft. per hour and the gas used having a net calorific value of 530 B.Th.U. per cubic foot. When in the molten state, the consumption

of gas required to maintain the metal at a temperature of 600° Fah. was 200 cub. ft. per hour, this corresponding to a gas consumption of 20·3 cub. ft. per cwt. for complete melting, and 5·7 cub. ft. per cwt. per hour for maintaining at a temperature of 600° Fah., these figures comparing very favourably with those obtained in the case of conical pots.

Fig. 2 represents a section of the duplex burner used, B being the double chamber cast-iron head, L the detachable lid, T ¾in. gas piping cut to any required length, and I the injectors fitted with the jets J and air regulating cones D. These burners are also used for sugar boiling, varnish making, and for the boiling of liquids in vats.

Fig. 4 represents a section through the ordinary basin-shaped conical cast-iron lead melting pot. Owing to the shape of these pots departing considerably from the hemisphere, we have deduced the following formula for obtaining the approximate capacity, which is:—

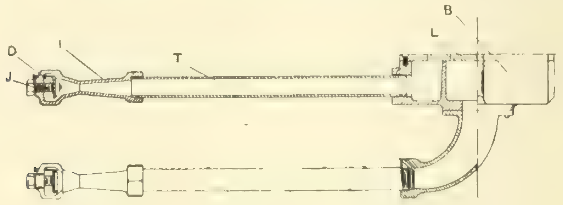


FIG. 2.—DUPLEX HIGH-PRESSURE CHAMBER BURNER.

If R = radius of surface of molten metal in inches.
d = depth from centre of metal surface to centre of bottom of pot in inches.
Then W = capacity of pot in pounds lead = ·215 $(R^2d + d^3)$.

Perhaps the more important point to be considered is the method of applying the gas to the pots to be heated. A number of important conditions have to be fulfilled if the highest efficiencies are to be attained. The temperature of the flames must be as high as possible. The flame shall be as close to the pot as possible without combustion being retarded. The film of gas always present on the outer surface of the pan shall be reduced to a minimum, in order that the temperature head shall not be lowered any more than is absolutely necessary. If it can be arranged, it is an advantage to introduce a mechanical stirrer into the molten metal. This serves the double purpose of interfering to some extent with the thin film of non-circulating metal in contact with the sides of the pot, and also bringing the large bulk of the metal into intimate contact with the hottest part of the pan.

What do we know about the temperatures of flames? And how are the highest temperatures to be attained in flames formed by the combustion of coal gas and air? We know that the temperature of a flame depends on: (1) The total heat generated by the combustion that has taken place. (2) The weight of gases—either products, diluents, or uncombusted gases—that hold this heat. (3) The specific heat of these gases at the temperature attained in the flame.

Undoubtedly, very useful relative figures may be obtained if such calculations are made. They are chiefly useful as indicating the conditions that will affect the temperatures attainable. The phenomenon of flame is not observable except when gases and vapours are undergoing combustion. It is, therefore, composed of the hot vapours and gases undergoing combustion, and frequently diluted with inert gases and products. The experiments of Smithells and Ingle (1892) are particularly interesting and useful in the light they throw on the structure of flames.

Complete Combustion.—As has already been indicated, complete combustion, even in explosion, is never instantaneous. The presence of any foreign gas interferes with combustion. Every portion of flame must contain combustible, burning, and already burnt substances. A certain space is required, and the temperatures will be unequal in different parts of it. The following are some of the factors that cause the actual temperatures attained in flames to diverge widely from those calculated:—

(1) Combustion is not instantaneous, and not confined to one spot.

(2) The reaction $H_2 + O \rightarrow H_2O$ is a reversible one at high temperatures. A different state of equilibrium exists between H_2, H_2O, and O_2 at each temperature, and, consequently, heat is not only being generated, but it is being absorbed.

(3) The specific heat of certain gases increases considerably at high temperatures. Holborn and Austin have shown that—

Between	110° C.	and 280° C.	the mean	specific heat of	steam	is	·465, while
,,	110° C.	,, 1,400° C.	,,	,,	,,	,,	·532, and
,,	110° C.	,, 200° C.	,,	,,	CO_2	,,	·217, while
,,	110° C.	,, 1,400° C.	,,	,,	CO_2	,,	·272, and
,,	110° C.	,, 200° C.	,,	,,	N_2	,,	·240, while
,,	110° C.	,, 1,400° C.	,,	,,	N_2	,,	·262.

As the temperature found in different parts of the flame is known to vary very considerably, it is impossible to take an accurate figure for any of these specific heats.

(4) There is an appreciable loss of heat by radiation—perhaps amounting to 10 per cent. in an average coal gas bunsen flame.

If none of these variations occurred, the temperature of detonating gas $(H_2 + O)$ would be calculated as 7,700° C. It is most nearly 2,000° C. When any but theoretical quantities of gases for the complete combustion of the gases are present, lower temperatures will be attained. Flames of coal gas and oxygen in theoretical proportions will have higher temperatures than flames of coal gas and air. In the latter case, the nitrogen, which is present in large proportions, acts as a diluent and absorber of heat. In a similar way, mixtures in which there is an excess of gas will produce flames of lower temperature than correct mixtures—the excess of gas acting as a diluent.

Where gas and air are used, the highest flame temperatures are obtained when a correct and efficient mixture of air and gas is made previous to combustion commencing, assuming, for the moment, that the question of preheating either is out of consideration. These correct mixtures may be obtained either by means of high-pressure gas and injected atmospheric air, or by means of air under pressure and low-pressure gas. We find that the most constant conditions are given by the former of these methods.

Reverting back to the original proposition, then—that of soft metal melting in iron pans—the highest efficiencies are obtained by means of the apparatus described, using high-pressure gas and chamber burners. The reasons are as follow: The combustion space is reduced to a minimum. The high velocity of the mixture of air and gas in contact with the pot clears away the inert gas film that reduces the head of heat in the flame. The temperature of the air-coal gas flames is at a maximum because the mixture is complete before combustion takes place, and there are no diluents in the flames due to excess of air or gas. [Very little secondary air is necessary.]

Compare these conditions with those found when using the best types of industrial low-pressure ring burners. The flame

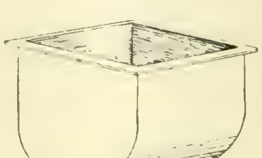


FIG. 3.—BATH-SHAPED LEAD MELTING POT.

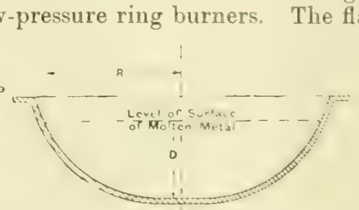


FIG. 4.—BASIN-SHAPED LEAD MELTING POT.

temperatures are from 200° to 300° C. lower than high-pressure flame temperatures. The temperature "head" is consequently much lower. The velocity of the gases escaping from the burner is not high enough to interfere with the pad of inert gases round the pot. After very exhaustive experiments, we find that, working with a pot as shown in Fig. 1, containing 3 cwt. of white metal, it is possible to maintain the metal at 650° Fah. with a consumption of 165 cub. ft. of high-pressure gas per hour; whereas it takes 250 cub. ft. of low-pressure gas to do the same work. By means of low-pressure gas, it was found impossible, whatever the consumption, to attain a temperature in the metal of 800° Fah., whereas there was no difficulty in doing this with high-pressure gas. With a larger quantity of metal, 2 tons, in a larger

pot, even 600° Fah. could not be attained by means of low-pressure gas flames.

Indirect Heating.—It has already been stated that for the purpose of the present discussion heating by means of gas may be considered as (1) direct (flame) and (2) indirect (radiation). In most heating appliances both systems are employed, but where the best results are to be obtained, it is necessary to distinguish between them in order that each may be manipulated and adjusted as best suits the conditions to be fulfilled. In crucible furnaces, by far the greatest part of the heating of the pot is by radiation from the furnace walls, but some heat is also conveyed to the pot from the flame and the hot products encircling the pot. In glory holes and ovens, the whole of the heating is by radiation, as the products do not come into contact with either the metal to be heated or with the pot, where one is used. Radiant heating, though indirect, is the more efficient if the furnace linings are satisfactorily made and the minimum amount of heat is allowed to escape through the furnace walls.

Recently, in melting furnaces, owing to the use of the sectional block linings and antithermic cement, it has been possible to reduce the gas consumption, in 160lbs. pot brass melting furnaces, by 15 per cent., the temperatures and times of melting being the same as employed with the old type of linings. With these linings it is much easier to get the temperatures required in nickel-melting furnaces.

It will have occurred to all furnace makers that to have to pass the heat in metal-melting furnaces through the walls of the retaining pots must be a source of serious loss. Direct heating of the metal would be an advantage if practicable. In all metals containing spelter this would not be practicable, as the losses of metal through localised heating would far out-balance the saving in gas. The reverberatory type of furnace is of this kind. The Le Chatellier oil furnace is in use in many places; but the metal losses must be enormous.

The relative advantages of low-pressure gas, air blast, and high-pressure gas systems depend on the local circumstances and the description of work that has to be carried out. Much experimental work remains to be done in the design of low-pressure gas-heated furnaces. In this type, there are great possibilities for regeneration—in pre-heating the air used in combustion. There are very satisfactory furnaces of this type at present on the market.

Surface Combustion.—During recent years much has been heard of this system for gaseous heating. Birmingham is perhaps the city that has the most to gain by improvements of this kind, and we had hoped to install many of these furnaces if the results to be obtained were what we had anticipated, and if the furnaces had been sufficiently lasting in construction to stand the wear and tear of normal works conditions. So far, we have had no evidence of any long period practical tests upon which to judge.

(To be continued.)

The Junior Institution of Engineers: Gustave Canet Lecture.—The members of the Junior Institution of Engineers have cause to congratulate themselves upon the announcement that the second Gustave Canet lecture will be delivered on the 29th anniversary of the foundation of the Institution—Monday, June 30th—by Dr. Dugald Clerk, F.R.S. It is also a happy coincidence that Sir Trevor Dawson, who delivered in so able a manner the first Canet lecture in 1909, is this year the president, and has consented to preside on this occasion. The subject chosen by Dr. Clerk for his lecture, viz., "The Working Fluid of Internal-combustion Engines," is one upon which he is particularly well qualified to speak. The importance of the subject itself at the present time can hardly be exaggerated. The internal-combustion engine is almost daily increasing its sphere of action; in aerial locomotion it is the only prime mover, and in marine work it is making rapid strides: on land, for both transit and stationary power, it is continually gaining ground, so that altogether the subject is one upon which it would be difficult to bestow too much attention. Visitors wishing to attend should make early application for tickets to Mr. A. Clifford Swales, secretary, 39, Victoria Street, Westminster, S.W.

VAPORISER FOR OPEN-HEARTH SUCTION PRODUCERS.

An arrangement of vaporiser for generating the steam used by open-hearth suction gas producers has recently been patented by Messrs. Crossley Bros., Ltd., Openshaw, Manchester. This is shown in the accompanying cut, and comprises means for supplying water to the stepped firegrate vaporiser in combination with two S sealed water pipes so arranged that by maintaining a constant feed to one an intermittent feed to the vaporiser is obtained, in accordance with the requirements of the engine.

Fig. 1 is a sectional elevation and plan of the producer; Fig. 2 is a sectional elevation, on a larger scale, of the vaporiser; and Fig. 3 is a similar view of the arrangement of two S sealed water pipes. In these views A designates the producer, which consists of a steel case with a cast-iron base ring B carrying the firebrick lining C. The casting B is supported by feet D, which also act as supports for the stepped firegrate E. The firegrate is composed of a series of circular plates arranged in steps in such manner as to be suitable for

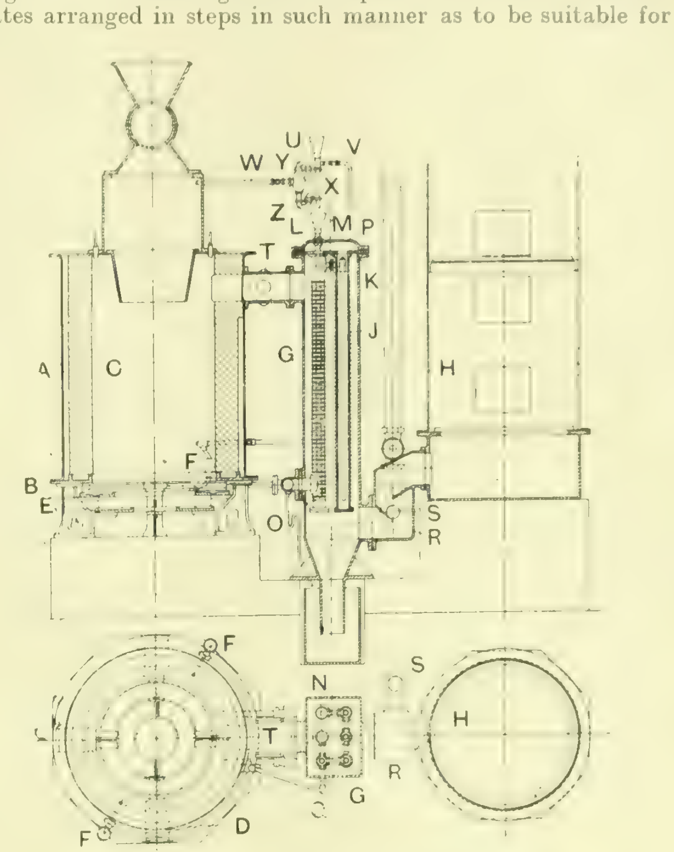


FIG. 1 VAPORISER FOR OPEN-HEARTH SUCTION PRODUCERS

the vaporisation of water run directly on to them from a supply pipe and funnel F. The external vaporiser consists of a casing G which affords communication between the generator A and the scrubber H. Placed in the casing or communicating pipe G are a number of gilled tubes J which are supported from a plate K in any suitable manner so as to allow for free expansion and contraction. Inside each gilled tube, with the exception of one, is fixed a small pipe for creating or inducing a regular circulation of the water. The arrangement of gilled tubes is such that the water for vaporisation passes into a funnel L and down to the bottom of the small tube M into the bottom of the gilled tube, up which it rises and overflows at the top into the centre pipe of its neighbouring gilled tube, and falls again to the bottom through the small tube and again rises in the gilled tube itself. This action proceeds through the entire nest of gilled tubes, whatever their number may be, and since the heat is greatest at the tops of these gilled tubes, by reason of their position relatively to the gas outlet of the generator, convection currents are assisted by the particular method of circulating the water. The last gilled tube N, as shown in the sectional plan, Fig. 1, is arranged without any internal small tube so that any water overflowing into this tube (which is primarily used as a steam heating tube) is carried away by the U shaped bend O shown in Fig. 1. The bottom of each

gilled tube is provided with a detachable flange so as to facilitate cleaning internally. The outside cover plate P is shaped to allow a suitable steam space at the top of the external vaporiser. A hot water overflow connection Q may be provided for the purpose of feeding the funnels F with hot water for the stepped grate vaporiser, but such funnels may

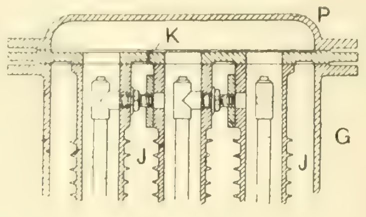


FIG. 2.

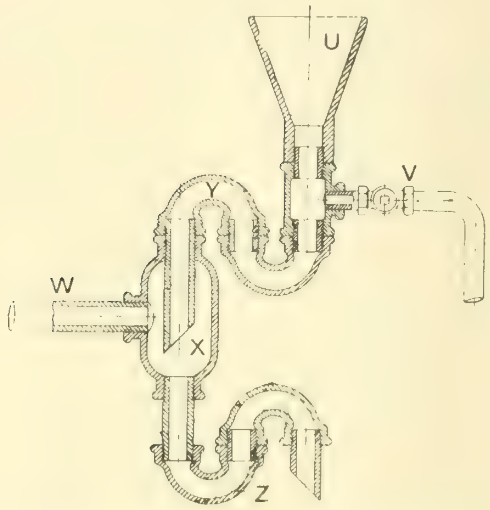


FIG. 3.—VAPORISING ARRANGEMENTS FOR OPEN-HEARTH SUCTION PRODUCERS.

be supplied directly from the water main. The bottom of the casing or communicating pipe G is carried with its open end into the seal box as shown in Fig. 1, and between this communicating pipe and the scrubber H a cascade pipe R is so placed as to ensure the hot gas passing through two or more cascades of water overflowing from the scrubber. The blow-off pipe may be placed either at S or alternatively at T, as indicated on Fig. 1. The water supply for the external vaporiser consists of the arrangement of two S sealed water pipes Y and Z and casing X, as shown best in the detail view Fig. 3. Normally all the water flowing into the funnel U overflows and runs to waste through the cock V. When the engine, however, takes a charge of gas a partial vacuum is created in the pipe W connecting the gas generator with the casing X, with the result that water is drawn over the top bend of the tube Y and drops into the lower tube Z and thence to the funnel L shown in Fig. 1. It will be seen that the lower tube Z acts as a seal to the casing X.

International Mining Congress, 1915.—The International Congress of Mining, Metallurgy, Applied Mechanics, and Practical Geology is to be held in London in 1915. Several preliminary meetings of the Organisation Committee have already been held, and a decision arrived at that the sections of the Congress be divided into four groups as follows: Group 1, mining: section A, coal mining; section B, metal mining; Group 2, metallurgy: section C, ferrous metals; section D, non-ferrous metals; Group 3, applied mechanics: section E, mechanical engineering; section F, chemical engineering; section G, electrical engineering; Group 4, geology. The presidents of the associated institutions in office at the time of holding the Congress are to be invited to act as chairmen of the sections, as follows: Coal mining, President, Institution of Mining Engineers; metal mining, President, Institution of Mining and Metallurgy; ferrous metals, President, Iron and Steel Institute; non-ferrous metals, President, Institute of Metals; mechanical engineering, President, Institution of Mechanical Engineers; chemical engineering, President, Society of Chemical Industry; electrical engineering, President, Institution of Electrical Engineers; geology, President, Geological Society.

SINGLE-PHASE TRACTION.*

BY M. LATOUR.

IN the first place the author proposes to make a few general observations in regard to the mechanical construction of single-phase locomotives and to the erection of overhead conductors. Some cognate questions will then be discussed, such as the very important subject of the disturbance caused to telephone and telegraph lines. Finally, some solutions of the problem of single-phase traction will be indicated.

Mechanical Considerations. — There are some general mechanical considerations which have no special relation to single-phase traction. In all cases there is the alternative of a crank or a direct drive. Opinions on this point are still divided. As regards the crank drive, some adopt dummy axles (Thomson-Houston) and others do not (Westinghouse). The respective methods are outlined below. It is convenient here to mention that the Oerlikon type of locomotive, however, is not fitted with dummy axles. Using cranks, the motors may or may not drive through gearing without the normal working being thereby altered to any extent. A point to which attention must be drawn in the case of single-phase traction is the advantage obtained by using springs.

The torque being oscillatory, an objection has already been raised that the whole weight of the locomotive is thereby not fully available for traction, and there will also be dangerous vibrations. As a matter of fact, this criticism does not seem to be entirely justifiable. In any case the use of springs is a complete safeguard against this. With springs dangerous resonance effects, such as arise at certain speeds with mechanical transmission, can be avoided, in so far as these arise from fluctuations in the torque. Equipments with springs exhibit, moreover, a somewhat curious property which I shall mention here. In this respect it can be said that the motor does not rotate at a constant speed throughout a whole cycle, but has an oscillatory movement in addition to its mean speed of rotation. It is by paying attention only to this oscillatory movement that it will be seen to be liable to produce a leading wattless electromotive force in the armature. This phenomenon has not been utilised in locomotives up to the present time, and will not have a promising future.

Overhead Conductors.—The overhead conductors have generally a catenary suspension. In the case of the catenary suspension the conductor is suspended from one or more overhead wires by means of hangers, of which the ends grip the upper half of the conductor, which is in the form of the figure 8. The object of this method of suspension is to ensure that the conductors shall be horizontal. Where there is only one

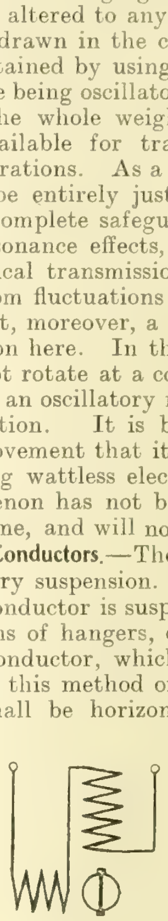


FIG. 1.

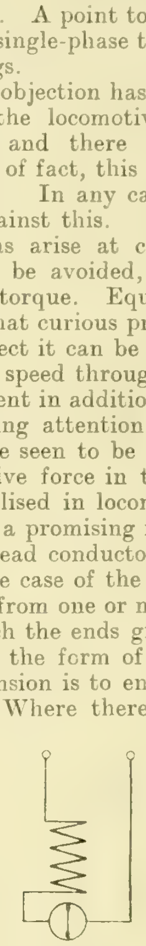


FIG. 2.

supporting wire there is a simple catenary suspension. Where two supporting wires are used, and the second is supported by the first, it is called a double catenary. When two supporting wires are used for the suspension of the conductor we have the triangular catenary suspension. This last has been set aside because it is too rigid. The double catenary suspension has greater flexibility, but it is also more expensive, and it is found that when the speed does not exceed 80 km. per hour the simple catenary suspension is adequate.

In order to avoid the effect of changes in the length of the cables, due to temperature variations, and the variable sag which results therefrom, balance weights or springs are often utilised, but this arrangement is not always considered advantageous. Passage through tunnels and over level crossings requires adjustments in the height of the conductor, and such adjustments would otherwise appear to be essential. As it is easily adaptable in this respect, provided that adjustments are made on a sufficiently low gradient, variations in the sag resulting from the diurnal temperature changes will

* Paper read at the Joint Meeting of the Institution of Electrical Engineers and the Société Internationale des Electriciens, Paris, May 21st-24th, 1913.

not influence appreciably the proper working of the line. The use of balance weights or springs increases the cost of the line, and their value is somewhat uncertain when the track has many curves.

It is desirable to avoid hard points in the line; and, similarly, heavy rolling stock should not be used lest the pantograph after being quickly depressed should break contact with the conductor owing to the shock. Care should be taken that the conductor is not made too heavy or too light. In the latter case the pantograph can raise the conductor, and if the suspension yields the pantograph may cause trouble. The type of pantograph to be adopted depends upon the kind of conductor. The more rigid the line the more flexible the collector must be, and vice versâ.

Another important question arises in regard to the conductors, and that is their insulation. In the case of a scheme

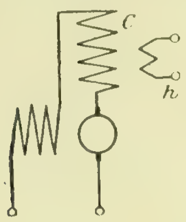


FIG. 3.

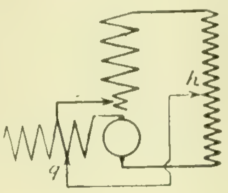


FIG. 4.

for working jointly by steam and electricity, care must be taken to use double insulation in tunnels and under bridges, since a good conducting carboniferous deposit liable to cause leakage may be formed.

The spacing of the standards being fixed at 100 metres, the Compagnie du Midi insisted on the use of "anti-oscillating" standards in the middle of each span. In view of the appreciable increase of cost due to these precautions, it may be convenient to adopt a smaller spacing. That which appears to be most suitable is one of from 60 to 70 metres. As regards the construction of the standards, it is proposed to use reinforced concrete posts as well as metal posts. Reinforced concrete posts have the advantage of a very long life, but they have the drawback of being heavy, and their total mass renders them cumbrous. Metal posts have the advantage that they can be built up of two parts, and, generally speaking, they are cheaper. The above considerations lead to the conclusion that the line should be made as simple as possible.

Motors. — The tests carried out by the Compagnie du Midi have been very interesting, because every type of motor has been tried. Perhaps a definite outcome will result from the tests which are proceeding in various countries, and possibly single-phase traction, with all the facts before us, will finally be appreciated equally by its advocates as well as by its opponents. Reference will now be made to the various types of motor which have been supplied to the Compagnie du Midi, and to the various speed-regulating devices of these motors. A few general observations will first be made. The motors experimented with, excluding the well-known Westinghouse series type, have been: (1) the simple repulsion motor (Brown, Boveri) and the compensated repulsion motor (A.E.G.); (2) the series motor with a transverse local field for compensating the electromotive force of short-circuit under the brushes (Jeumont) and the series motor with an elliptical field (French Thomson-Houston Company).

Repulsion Motors. — (1) The simple repulsion motor is shown in Fig. 1. As the present author has shown, there is found in the repulsion motor, due to the current produced in the short-circuited coil by its rotation, a transverse field which interacts with the main field so as to give a synchronously rotating field, thus ensuring satisfactory commutation at that speed. This simple observation, which previous authors (Steinmetz and others) have overlooked, has settled the future of the repulsion motors. At speeds above synchronism, however, the transverse field increases in strength, the commutation becomes unsatisfactory, the iron losses increase, and at speeds above $\sqrt{2}$ times synchronous speed the commutation of the repulsion motor becomes worse than that of the series motor.

(2) I have given the name compensated repulsion motor to the motor shown in Fig. 2. This motor has the essential characteristics of an ordinary repulsion motor. It has, moreover, the advantage of working at approximately unity power factor, due to the property of commutator motors with short-circuited brushes having no inductance at synchronous speed and negative inductance above that speed, even when supplied with simple alternating current.

Series Motors. — The arrangement in a series motor with an artificial transverse field which neutralises the electromotive force of short-circuit as happens naturally in repulsion motors at synchronism, was first described in the German Patent No. 162781 of the Maschinenfabrik Oerlikon, March, 1904, and in the author's Austrian Patent No. 235502 of April, 1904 (French Patents: Latour, No. 342571; Oerlikon, No. 354449).

(3) A series motor of the type described in this last patent is shown in Fig. 3.* The winding h can be connected in shunt to the terminals of the motor. If it is assumed that the compensation in the motor is provided so as to ensure perfect commutation with continuous current, it is clear that the winding h should carry a current 90° out of phase with the main current. But the winding h can be allowed to assist compensation, and in this case such winding, in addition to the current which is 90° out of phase, will carry a current in phase with the main current. If, on the other hand, overcompensation takes place with the winding C, the winding h will carry a current opposed to the main current.

(4) I have given the name elliptical field motor to the motor arranged as shown in Fig. 4. In this arrangement a short-circuit is established between the point G of the exciting winding, which can be extended for this purpose, and the point h of the transformer supplying the motor. Apart from the ordinary compensation, which would give good commutation in the case of continuous current, a local strengthening of the field can be provided, as is shown in Fig. 4; it follows that the point g should not be so far removed from the rotor. I have already published a detailed theory of this motor. Attention has since been called to somewhat similar earlier arrangements of this nature, but it will be clearly seen that no one previous to the author had either understood or indicated precisely the correct conditions for securing perfect commutation. Having reviewed these four types of motors, it is now proposed to make a systematic comparison between them.

Contact Surface. — By rubbing surface we mean the contact area of the brushes on the commutator. The reduction in the contact surface is the important feature in alternating-current machines provided with a commutator. If the starting torque with satisfactory commutation is represented by C, and

FIG. 5.

FIG. 6.

ω represents the maximum angular velocity when the motor is running, we have already suggested in the "Electrical World" that the following produce—

$$C \omega = P$$

should be taken as one of the essential characteristics of the power of the motor.

Thus, if—

f = frequency of the supply current,
t = peripheral speed of the commutator at angular velocity ω,
a = width of the brushes,
v = the pressure between the two edges of the brush,

and—

I = current in the commutator,

we have already proved that whatever the type of motor and the number of its poles, or whatever form of winding is adopted, in every case we have the relation—

$$v\,I = \frac{\pi\, a\, f}{t}\, P \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

For a given power P, if f, a, and v are given, it is only necessary to reduce I, that is to say the surface of contact, in order to increase the peripheral velocity t. Thus until t has been chosen, the product v I may be taken as constant in the

* In accordance with my Patent No. 342571, the winding h could be distributed round the surface of the stator.

case of the motor under consideration, and if we suppose the contact resistance of the brushes to be constant in these circumstances, it is easily shown that the losses on the commutator are a minimum when the losses due to the current are equal to the losses due to the short-circuit currents. If we denote by k the decrease of resistance under the brushes due to the current I, this is exactly what occurs when the pressure between the segments is such that $e = 2\cdot45\ k$ when the brushes cover only one segment, and such that $e = 1\cdot55\ k$ when the brushes cover two segments of the commutator.

In this connection it should be remembered that the losses due to the short-circuit currents under the brushes are all the smaller, for a pressure v between the edges of the brushes,

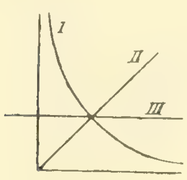


FIG. 7.

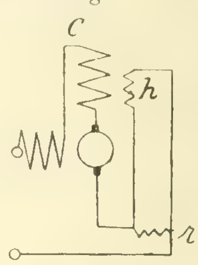


FIG. 8.

when this pressure is divided up among a large number of segments. With an infinite number of segments the losses would be reduced to half those for a commutator having only one segment. And with two segments they are already reduced to $\frac{5}{8}$ths.

Let us assume that the working conditions are so arranged that there is a minimum loss at starting, and let q stand for the quantity of heat set free per square centimetre of contact surface on the commutator, a quantity which defines exactly the character of the commutation. We have then shown that in the case where the brushes cover one segment the total rubbing surface is equal to—

$$S = \frac{2\pi}{\sqrt{1\cdot5}} \cdot \frac{af}{tq} P \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The total quantity of heat liberated on the commutator is given by—

$$Q = \frac{2\pi}{\sqrt{1\cdot5}} \cdot \frac{ai}{tq} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

The following relations hold when the brushes cover two segments—

$$S = \frac{2\pi}{\sqrt{2\cdot4}} \cdot \frac{af}{tq} P \quad . \quad . \quad . \quad . \quad . \quad . \quad (2a)$$

$$Q = \frac{2\pi}{\sqrt{2\cdot4}} \cdot \frac{af}{t} P \quad . \quad . \quad . \quad . \quad . \quad . \quad (3b)$$

It should be noticed that these expressions take no account of the nature of the brushes. To ensure a minimum loss the nature of the brushes should be chosen according to the pressure v between their extreme edges. We shall then have either brushes of high conductivity with a low value of v and a high value of I, or brushes of a high resistance with a high value of v and a low value of I. It follows, therefore, that the better results obtained by working at low densities will lead to the choice of brushes of high resistance adapted for use where v is high and I is low.

All the above formulæ show the decided advantage of a high peripheral speed for the commutator. To obtain these high peripheral speeds high-speed motors should be used. But high speed requires the introduction of gearing. This is the feature of the Jeumont and Westinghouse locomotives, as well as of the Oerlikon locomotive at Lötschberg. Gearing appears to give entire satisfaction from the mechanical point of view.

It is well, however, to notice that a reduction in the area of the contact surface, S, if it involves a corresponding reduction in the electrical losses on the commutator, does not result in a corresponding reduction of the mechanical losses. With constant pressure on the brushes the latter losses are independent of the permissible peripheral speed. From this point of view, theoretical working would consist in running at all speeds at the maximum flux which gives the short-circuit pressure v whilst making it possible to lift those brushes which have become unnecessary owing to the reduction in the current. I had already proposed this previously.

It should be noted here that high speed is not in principle incompatible with any type of repulsion or series motor. But it so happens that in the case of the repulsion motor, where the number of poles is determined by the number of conductors, a frequency of 15 leads to a motor with a small number of poles. Let us next consider in turn the disadvantages which arise from this situation.

(1) It would seem to be difficult to obtain a pressure between the segments low enough for large powers, but the arrangement of having two short-circuits has been suggested (see Fig. 5), in which the brushes would be placed in a position where the pressure between the segments is still lower; and I have also suggested the use of independent overlapping windings, and especially the arrangement of two overlapping windings with two commutators.

(2) A doubt may arise whether it is possible to arrange for a sufficient number of sets of brushes to carry the current. My arrangement of multiple brushes (see Fig. 6) would, however, at the same time do away with this difficulty.

(3) Trouble may arise due to lateral lack of room, but recourse may be had to short-pitch flat connections, as has already been seen.

(4) At the same time, it may be feared that it will be impossible exactly to compensate what certain authors term "reactance pressure," but this may be provided for by suitable windings on the stator and rotor. In this connection it should be noticed that the bad commutation of repulsion motors is often wrongly attributed to over-synchronism. Faulty compensation is alone responsible in such cases.

From this it should not be imagined that the repulsion motor cannot be constructed for the same speed variation as the series motor. It should, however, be observed that for a given power a certain pressure between the segments at starting is more dangerous when the machine has fewer poles. This depends on the fact that the impedance of the short-circuited sections—which is due to leakage and to the resistance of the windings, and which has an influence in limiting the short-circuit current—is relatively much greater as the power per pole is smaller.

Weight. — The inferiority of the repulsion type of motor at a frequency of 15 appears to lie in its weight, and indirectly in its lower efficiency. In consequence of the smaller number of poles, the repulsion motor requires a greater amount of iron; a larger external diameter is necessary, or, on the other hand, for a given external diameter a smaller bore has to be used, thus leading to a less advantageous utilisation of the material. We have already observed that whatever may be the frequency the efficiency of the repulsion motor remains

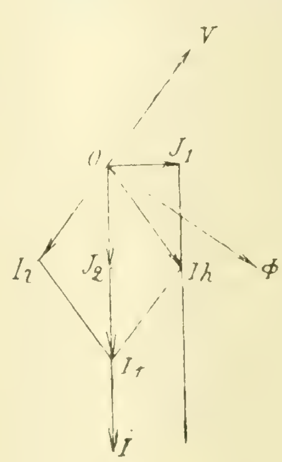


FIG. 9.

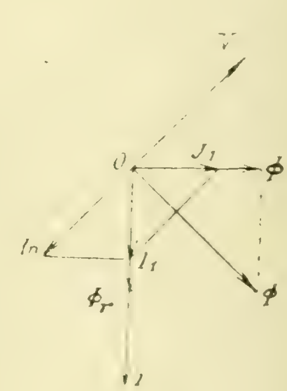


FIG. 10.

in principle identical with that of a single-phase alternator of the same frequency, whilst the efficiency of a series motor tends at lower frequencies towards that of a continuous-current machine. The difference in efficiency between the two types of motor is thus appreciable at a frequency of 15.

Commutation at Variable Speed.—The transverse field, which is 90° out of phase, and is required to neutralise the short-circuit electromotive force varies directly as the current and inversely as the speed. Supposing the excitation is provided by constant current the resultant field of commutation is a function of the speed, as represented by the hyperbola in Fig. 7. All the types of motors to which we have referred

above, even the series motor of which the auxiliary pole is in shunt with the terminals, possess, so long as their circuits are not modified, a transverse field 90° out of phase, which increases linearly, as is shown by the line in Fig. 7. Accordingly, the electromotive force v of short circuit can only be neutralised satisfactorily for a certain speed ω. The resulting pressure which appears in the short-circuit at speed ω is proportional to $v\left(1 - \frac{\omega_1^2}{\omega^2}\right)$.

It is therefore quite natural to think of adjusting the transverse field according to the speed. In the repulsion types of motor it is possible to screen locally the transverse flux at speeds above synchronism. In series motors the supply in the coil h of Fig. 3 can be adjusted, or the connection shown as $g\,h$ in Fig. 4 may be moved. These adjustments can be carried out by a centrifugal governor, or by an electrico-dynamical speed device. Complications, however, arise in this respect. It should be noticed that the presence of true commutating poles in repulsion motors detracts from the simplicity of their construction and connections as compared with the series motor. If simple arrangements could be fitted so as to ensure a transverse field suitable for all speeds and for effecting satisfactory commutation, such arrangements would then be preferable. It is from this point of view that we shall study the current in the winding h of Fig. 3 connected across the terminals of a resistance r through which the principal current of the motor flows (see Fig. 8).

It is seen at once that with this arrangement the transverse field will be proportional only to the current, and will be independent of the speed. It is represented by the horizontal line III in Fig. 7. The pressure in the short-circuited coil, which will appear this time at a speed ω_1 differing from the speed ω for which there is perfect neutralisation of all electromotive force, will be $v\left(1 - \frac{\omega_1}{\omega}\right)$ instead of $v\left(1 - \frac{\omega_1^2}{\omega^2}\right)$.

In other words, with variable speed, the commutation of a ploypháse series motor is substituted for that of a repulsion motor.

The arrangement with the resistance is therefore of greatest interest, and we now have to determine what energy is dissipated in the resistance. Let us suppose that we have a winding h of n turns, and that by means of a suitable series transformer we could always supply it with a current I, say. The winding h not only encloses the flux which is 90° out of phase and which should neutralise the pressure v, but it also encloses the opposing flux the object of which is to ensure good commutation with continuous currents. This opposing flux can be produced either wholly by the compensating winding C or wholly by the winding h, if the compensation only neutralises the rotor field in the stator in the same manner as the short-circuited winding C. It can be finally produced in part by the winding h.

Whatever method be used, however, as soon as the number of turns n is determined, the pressure at the terminals of the winding h will be constant whatever the function of h may be. As a first approximation we shall neglect the resistance of the winding h. Let us take as our standard of reference the phase of the current I, which is that of the main field of the motor. The resultant flux ϕ, enclosed by the winding h, is, for a given motor, determined in magnitude and phase. The electromotive force induced by the flux ϕ at the terminals of h has a direction perpendicular to that of ϕ. The current I which circulates in the resistance has a direction opposed to this pressure. The current circulating in the winding h is at first the current J_1, capable of producing a transverse field which is 90° out of phase, and afterwards a current J_2 in phase with I, which has a variable value depending on the amount of compensation provided by the winding h. The resultant of J_1 and J_2 is I_h. We know that the resultant of I_r and I_h, *i.e.*, I_1 must be in phase with I; from this fact I_r may be determined, if I_h is known, by drawing a line parallel to O V from the point I_h.

It is seen from Fig. 9 that, whatever may be the value of the current J_2 in phase with the current I which circulates in the winding h, the point I_h remains on a line parallel to O I, and that consequently the current I_r remains constant as well as V. The losses in the resistance, equal to V I_r, accordingly remain constant, whatever adjustment may be made. The adjustment of J_2 has simply the effect of varying the value of the current I_1 which we require according to the number of turns n selected for the winding h. J_2 can be chosen in such a way that I_1 is equal to I.

As the losses are independent of the value of J_2, we can consider the special case where the winding h carries the current 90° out of phase with reference to I (see Fig. 10). We shall study the losses a in this case. Let R be the reluctance of the magnetic circuit of the winding h and θ be the angle I O ϕ, then—

$$V = 2\pi n f \phi$$

$$J_1 = \frac{R}{4\pi n}\phi \sin\theta,$$

$$I_1 = \frac{J_1}{\cos\theta} = \frac{R}{4\pi n}\phi \tan\theta.$$

Therefore—

$$a = V \times I_1 = \frac{R}{2} f \phi^2 \tan\theta.$$

The flux is the resultant of two fields 90° out of phase, *i.e.*, a reversed field ϕ_r in phase with I and a transverse field ϕ_t 90° out of phase in regard to I. The expression $\frac{\phi_t}{\phi_r}$ is exactly equal in magnitude to tan θ, and, other things being equal, it is immediately seen that this expression is proportional to the frequency of the supply current. We have therefore—

$$\tan\theta = k f,$$
$$\phi^2 = \phi_r^2 + \phi_t^2 = \phi_r^2\,(1 + k^2 f^2).$$

The expression for the losses a then takes the form—

$$a = \frac{R}{2} k f^2 (1 + k^2 f^2)\,\phi_r^2 \quad . \quad . \quad . \quad (4)$$

This becomes, for a motor having $2\,p$ poles—

$$p\,\frac{R}{2} k f^2 (1 + k^2 f^2)\,\phi_r^2 \quad . \quad . \quad . \quad . \quad (4a)$$

It will be understood to how great an extent they are affected by the frequency f, since it is almost the fourth power of the frequency which is involved. Whilst the use of a resistance may be practicable at 15 periods, it may be expected to be inadmissible at 25 periods. It is equally important to notice the effect of the number of poles on these losses. It is found that the total losses A for the motor vary at least inversely as the number of poles. It is therefore desirable, with a view to reducing the losses a, to increase the number of poles.

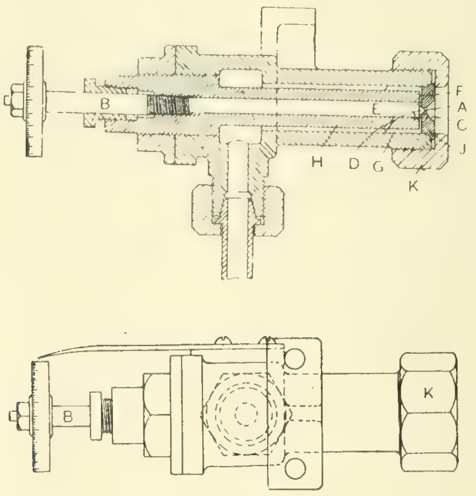
It may also be asked what happens in a motor having a given number of poles when its speed of rotation is increased. Under these conditions the more the speed rises above synchronism the smaller the out-of-phase field needed; this is expressed in the formula by the fact that k varies inversely as the speed. The losses, however, diminish proportionally with R^3. It is clear, therefore, that the narrower the auxiliary poles, the smaller are the losses. To bring about this reduction, a small tooth pitch must be used for the rotor. The effect of the width of the poles is shown in formula (4a) above, by the presence of the term $R\phi_r^2$ ($= R\phi_r + \phi_r + \phi_x$), a value independent of the width, but ϕ_r is determined by the width of the poles. The importance of small air gaps is thus seen; for R diminishes as ϕ_r diminishes.

It follows from formula (4a) that in order to reduce the losses a it is convenient, a low frequency and narrow auxiliary poles having been chosen, to work with reduced air gaps, high speeds, and a large number of poles. At a frequency of 15 periods these losses can be reduced to the negligible value of $\frac{1}{3}$ or $\frac{1}{4}$ of 1 per cent.

It might be thought that the author has been led to the idea of the artificial creation of a transverse field in the series motor (Austrian Patent No. 23502) as a result of his observations on the repulsion motor. As a matter of fact, the author arrived at his results in exactly the opposite way. An article on the use in a series motor of auxiliary poles excited by a current suitably out of phase was sent by the author to "Eclairage Electrique" in January, 1901; this article was not published, but the original communication was returned to the author with some comments by Prof. Guilbert. It is as a result of the automatic formation of a similar transverse field in repulsion motors that the author at first condemned the series motor with auxiliary poles.

KERMODE'S LIQUID FUEL BURNER.

Mr. J. J. Kermode, of 62, Dale Street, Liverpool, has introduced several improvements in his design of liquid fuel burner, and these are shown in the accompanying illustration. The perforation A is made conical, instead of sharp edged, on the side next to the central spindle B, the other side being widely flared at C. The angle of the cone is comparatively obtuse, say 90°, and the conical projection D is made to the same angle, so that when the spindle is screwed up, the conical projection fits and closes the conical central opening, the axial pressure being distributed over the whole of the conical surfaces and thus preventing damage to the nozzle or the projection by rough



Kermode's Oil Burner.

usage. This is an important matter, as the best results cannot be obtained unless the substantial accuracy of these surfaces is maintained. The axial position of the spindle B when the closing takes place is such that the annular end E of the spindle is some distance back from the inside face of the nozzle, so that when in this position the body of the spindle does not obstruct the oil ways F cut in the face of the plug end G of the inner barrel H. When therefore the spindle is retreated so as to open the nozzle, there is always a free way for the oil from the oil ways F to the nozzle, round the conical projection. The nozzle is formed in a separate plate or plug J, of hard steel. This plug has a short cylindrical part fitting in the bore of the main body and it has also a coned part fitting in a correspondingly coned seating in the end of the main body, so that it is adapted to be firmly held oil-tightly and in accurate alignment by screwing up the capped nut K.

INDUSTRIAL AND TRADE NOTES.

Last Year's Coal Exports.—Last year 64,444,395 tons of coal were exported from the various ports of the United Kingdom to places abroad, of which 54,741,963 tons sent were from England and Wales. In 1911 the quantity exported was 64,599,266 tons.

Destructive Fire at a Blackburn Engineering Works.—The extensive engineering works of Messrs. Yates & Thom, Ltd., Blackburn, were partly destroyed by fire on Sunday morning last, and the damage is estimated at £150,000

Mansfield's New Railway.—There was opened for traffic on Monday last half the ten-mile line of railway which is to connect the Great Central main line at Kirkby in Ashfield with that at Clipstone, and reduce the journey from Grimsby to London by 18 miles or so. The new line, which the G.C. Railway will work, is of importance to Mansfield, where it will serve the coal pits in that rapidly-developing district.

Proposed Engineering Works for Canada.—It is officially announced that Messrs. Armstrong, Whitworth, & Co. have purchased 250 acres on the south shore of the St. Lawrence, opposite the city, as a site for large steel works. A million dollars is to be spent at once on the construction of buildings covering 70 acres. It is understood that this is likely to be an important addition to the enterprises of the Elswick firm. Sir Percy Girouard and Sir G. H. Murray, directors of the firm, have just returned from Canada, where they have been negotiating for the site. Other British shipbuilding interests have been prospecting on the banks of the St. Lawrence.

Contracts for Motor and Train Equipment for the L. and S.-W. Railway.—The London and South-western Railway Company has let the contract for motors and train equipment for the first portion of its electrification scheme to the British Westinghouse Electric and Manufacturing Company, Ltd., Manchester. The conductor rails it is purchasing from Messrs. Bolckow, Vaughan, & Co., Middlesbrough, while the high-tension cables are being obtained from Messrs. Siemens Brothers & Co., Ltd., Woolwich. The contract for the power-house has not yet been let, but it is understood that 10,000 kw. and 5,000 kw. units will be installed, generating at a pressure of 11,000 volts. The sub-station equipments have been placed with the British Thomson-Houston Company, Ltd., Rugby. The first section to be completed will be the two lines to Hampton Court.

Production of Copper in the United States.—An advance report on the production of copper in 1912, issued by the United States Geological Survey, states that the smelter production of primary copper in the United States last year was 1,243,268,720lbs., as compared with 1,097,232,749lbs. in 1911, an increase of about 13·6 per cent. The total value of the 1912 output at an average price of 15·6c. per pound was $205,139,338, as compared with $137,154,092 in 1911. The total output of new refined copper in 1912 was 1,568,104,478lbs., which was the largest in the history of the industry, and exceeded the output of 1911 by 134,229,452lbs. Returns from all smelting and refining companies show that on January 1st, 1912, the stocks of electrolytic, lake casting, and pig copper were 88,372,195lbs., and that on January 1st, 1913, the stocks on hand were 105,497,683lbs.

Improvements of Kaiser Wilhelm Canal.—H.M. Consul-General at Hamburg reports that the work of widening and deepening the Kaiser Wilhelm Canal is nearing completion, and that the canal will be open to the largest ships probably by October next. The new works include locks at Brünsbuttel 146ft. broad and 1,072ft. long, and a navigable channel 45½ft. deep throughout the whole length of the canal. The new line of the canal is a considerable modification of the old one, with the result that two islands have been formed, one of which is to serve as a coaling station. Railway lines have had to be diverted, and the line to Flensburg will be carried over the canal by a high level bridge, 146ft. above the level of the water. This bridge is one of three arches, and the centre span (453ft.) carries the girders and rails of the aerial ferry (Schwebefähre) which has been provided for road traffic. It is understood that the total cost of the present works will exceed 12½ millions sterling.

Shale Miners and Safety Lamps.—The Home Secretary has now forwarded his reply to the Scottish Shale Miners' Association in regard to the two petitions recently lodged, asking that shale miners should be exempted from the use of safety lamps, and also from the Explosives Order contained in the Coal Mines Act of 1911. The general terms of the Home Secretary's reply are unfavourable to the granting of the petitions. The letter states that there is no power to exempt any class of mines from the provisions regarding safety lamps. The section of the Act only gives power to the Secretary of State to exempt particular mines, and only where he is satisfied that on account of the special character of the mine the use of safety lamps is not required. Each case therefore must be considered as it arises, and due weight would be given to all the circumstances prevailing. As regards the Explosives Order, the Home Secretary finds no grounds for distinguishing between oil shale mines and other mines, and regrets that he cannot see his way to vary the provisions in question.

British Engineers and the Chinese Market.—A meeting of the British Engineers' Association was held at Glasgow on the 12th inst., with the object of directing attention to unfair competition, particularly in regard to China, and with a view to devising means to overcome the obstacles which tell against the interests of British manufacturing engineers. Captain Fitz Hugh, chief commissioner of the association in China, said that the progress of events in China showed that presently there would be a huge market for engineering plant. China during the last twelve years had built 5,000 miles of railway, and soon there would be an enormous market for railway material. If the country continued to prosper, as he believed it would, it would need an efficient army and navy, and a market would be opened for munitions of war. If the present apathy in regard to Chinese trade continued this country would find that her prestige would dwindle to a mere fraction of what it used to be. The British Engineers' Association had been recognised by the Foreign Office, and their members were now in a position to claim official support. Members could by collective action control the conditions of tendering both in the home and foreign markets. In this way objectionable clauses could be successfully combated. Moreover, members could obtain business from their fellow members. Indeed, there was a growing tendency for members to place orders with each other, and the secretary was often applied to for the names of members who manufactured some particular article.

Extensions at the Spring Vale Steel Works.—Alfred Hickman, Ltd., Spring Vale, are at present engaged upon extensive alterations and additions which will result in considerably increasing the output of steel. Within the last three weeks a new Siemens plant has been inaugurated and is now in regular operation. It consists of a 40/60 ton tilting furnace, which is the first of a range it is proposed to erect, and it is stated that the furnace will make from 700 to 800 tons of the highest-class steel per week. The furnace is served by a Wellman Seaver charging machine, a 40-ton hot metal crane, and a 75-ton steel casting crane. In connection with the steel-making plant a 500-ton mixer furnace is being put down, and this will be served by Mond producers at present in course of erection. To provide for the additional output of slag, and to make room for the large mixer furnace, Messrs. Hickman are removing their existing slag-grinding plant to another site. The slag plant, when completed, will have a grinding capacity of 1,500 tons per week of Bilston basic phosphate. The new plant is entirely driven by gas engines operated by blast-furnace gas. Another large gas engine and dynamo, to provide the additional power required in the works, are being erected in the new power house. The engine is of 1,000 h.p., and its installation will give the gas-power plant at Messrs. Hickman's works a capacity of 14,000 h.p. A briquetting plant for dealing with fine ores is also in course of construction.

The Proposed Manchester International Exhibition. Two important meetings were held in Manchester last week in connection with the proposed international exhibition for Manchester. At the first of these, held on the 11th inst., the scheme was considered by the directors of the Manchester Chamber of Commerce, and it was unanimously resolved: "That the proposal to hold an international exhibition in Manchester does not command the approval of the Board of this Chamber. It is the opinion of the representatives of all sections of trade and manufacture than an exhibition is not desired, would not contribute to the development of the industries and commerce of the district, and is not likely in these circumstances to be a success." The second meeting was a public one, and was held in the Manchester Town Hall on the 13th inst., with the Lord Mayor in the chair. The general feeling of the meeting was that the exhibition should not under any circumstances be held before 1915 or 1916. The meeting finally voted in favour of an exhibition, 88 for and 18 against. The resolution in favour of the exhibition was moved by Mr. Albert Nicholson, who declared that those he spoke for were determined to have no exhibition for profit He believed that 1915 would be a more suitable time to hold the exhibition than next year. The only thing the committee had done so far was to secure the option of taking a piece of land suitable for their purpose. The area was 90 acres and was approached by two railway systems, and there would be good tramway facilities. The Lord Mayor said he was a little disappointed there had not been a larger gathering to consider such an important proposal. If the resolution were carried it should be submitted to a further meeting, which he hoped would be better attended. The resolution was carried, as stated, and it was then proposed that the exhibition should be held in 1916, but an amendment was carried to leave this question to the decision of the committee. Those who were present at the meeting were requested to send their names to Mr. J. H. Worthington, secretary to the Exhibition Committee, 13, Spring Gardens, Manchester.

Eight-hours Day in the Shipbuilding Trades.—The June report of the Boilermakers and Iron and Steel Shipbuilders contains the result of the voting of the members of that association on the following questions: (1) Are you in favour of an eight hours day in a form suitable to the exigencies of your trade, with rigid restrictions of overtime? For 5,287, against 578—majority for 4,709. (2) Are you in favour of obtaining an eight-hours day and restrictions or abolition of overtime by negotiations? For 4,426, against 607—majority for 3,819. (3) Failing in negotiations, are you in favour of giving support through the Parliamentary Committee to any affiliated societies or federations in fixing a date on and after which none of their members will work more than eight hours in any one day? For 4,509, against 675—majority for 3,834. (4) Are you in favour of the Parliamentary Committee pressing forward an Eight Hours Bill, and thus supporting industrial action by political action so as to make a general eight-hours day the law of the land? For 5,340, against 581—majority for 4,759. These results, it is added, have been sent to Mr. Bowerman, secretary of the Trade Union Congress; and Mr. Mosses, secretary of the Federation of Engineering and Shipbuilding Trades. In his remarks Mr. John Hill, the general secretary of the society, states that "our votes on the eight hours question have resulted in big majorities for each of the four propositions. All trades are marching together on this question. It takes time to move and organise the many thousands concerned, but they are now moving together along converging lines towards a common object, and its complete accomplishment ought not to be much longer delayed."

The Conference on Shipyard Wages.—The strike of shipyard workers, which was to have been inaugurated at the end of last week if the Shipbuilding Employers' Federation did not grant the full advance of wages demanded by the Standing Committee of the Shipyard Trades and the Executive Council of the Boilermakers' Society, has been postponed pending a fresh ballot of the members of the trade unions concerned. At the resumed conference held in Edinburgh on the 11th inst. between the Executive Board of the Federation and representatives of the men the employers stated emphatically that they could not amend in any way the offer which they made to the unions at the previous meeting. This offer was that they would grant an advance of 1s per week, or ¼d per hour, to all time workers, to take effect from the first full pay in August; this offer to be subject to acceptance by the Boilermakers' Society as a full settlement of their claim for a general advance; that they would grant the special advance of 2½ per cent. to rivetting squads—on behalf of the holders-up—and that there should be no further alteration in wages for a period of twelve months. The representatives of the men could not see their way to accept this offer, as their original demand had included a request for a 5 per cent. advance to all pieceworkers. After considerable discussion the representatives of the workmen decided to put the employers' proposals before all the trades in the shipyards affected for their vote and decision, and that meantime the strike notice, which was to have taken effect on June 14, be suspended.

Employment in the Engineering Trades.—The report of the Labour Department of the Board of Trade on the state of the labour market in May, states that employment continued on the whole very good. There was a considerable improvement in the tinplate industry. On the other hand, employment at iron and steel works, though still good, showed a further decline. Employment in coal mining, engineering, and shipbuilding remained at about the same high level as in April. The upward movement in wages continued. Compared with a year ago, most of the principal industries showed an improvement, which was most marked in the coal-mining, engineering, and shipbuilding trades. Trade unions with a net membership of 910,692 reported 17,138 (or 1·9 per cent.) of their members as unemployed at the end of May, 1913, compared with 1·7 per cent. at the end of April, 1913, and 2·7 per cent. at the end of May, 1912. Returns from firms employing 420,327 workpeople in the week ended May 24th, 1913, showed a decrease of 0·1 per cent in the number of workpeople employed and of 1·6 in the amount of wages paid compared with a month ago. Compared with a year ago there was a decrease of 0·3 per cent. in the number of workpeople employed, and of 0·6 per cent. in wages paid. The number of disputes beginning in May was 136, and the total number of workpeople involved in all disputes in progress during the month was 149,812, compared with 80,110 in April, 1913, and 99,156 in May, 1912. The estimated number of working days lost by disputes in May was 1,088,800, as compared with 588,400 in April, 1913, and 981,700 in May, 1912.

German Trade in 1912.—The Consular report on the trade of Germany for the year 1912, just issued, states that from an economic point of view the year was one of many records, due to a record demand at home and abroad. The value of the German exports amounted to over £450,000,000, against £410,000,000 in 1911; the value of the imports amounted to, roughly, £535,000,000, against £500,000,000 in 1911. The amount of coal produced was 177,000,000 tons, as compared with last year's figures of 160,000,000 tons. Continuing, the report says the steamship companies benefited from the great industrial activity, and 1912 will always be reckoned amongst their best years. For German shipbuilding (mercantile marine) 1912 establishes a record. In German yards there were constructed in 1912 375,317 tons against 255,532 tons in 1911, an increase of nearly 50 per cent. The orders in hand at the end of 1912 by far exceed all previous returns. Generally speaking, it can be said that the international trade between the United Kingdom (her best customer) and Germany shows fewer changes in 1912 than in 1911. The great boom of 1912 has, with the exception of the iron trade, had less effect upon the trade between the two countries than might have been expected. In the total for 1912 increases were balanced by decreases. These two highly developed economic entities have for a long term of years indulged in such an intimate exchange of goods that its general possibilities appear nearly exhausted. In spite of very great efforts there is hardly any progress; a stage of satiety has been all but reached. Raw materials, agricultural produce, and iron products are the pillars supporting this whole foreign trade

The best chances of future developments seem to lie, as far as the German export to the United Kingdom is concerned, in the results which German scientific methods achieve in their application to industry; as far as the British import into Germany is concerned in an increasing taste which grows with this German prosperity for British comfort, refinement, and luxury. There can be little doubt that if the British traders made determined efforts in that direction they could succeed in still considerably increasing the value of British exports to Germany.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Automatic safety apparatus for pit cages and lifts. Adams and Bythway. 1710.
Valve mechanism of internal combustion engines. Vickers, Ltd., and Bourcier. 9927.
Internal combustion engines. Vickers, Ltd., and Bourcier. 9938.
Lubricating pumps. Vickers, Ltd., and Bourcier. 9966
Superheaters. Heenan & Froude, Ltd., and Coates. 10007.
Furnaces for melting and alloying metals in vacuo. Simpson. 12067.
Driving gear for mechanically propelled tramcars. Nelson. 12184
Motor cars. Bishop. 12239.
Manufacture of metallic bars from finely divided metallic powders Gladitz 12244.
Axle trucks for railway vehicles Warner International and Overseas Engineering Company, and Hour. 12329.
Aerial craft. Cody. 12348.
Furnaces for metal heating, and metallurgical purposes. Hill. 12349.
Safety apparatus for signalling on and stopping trains independently of the driver. Wittlake. 12371.
Shock absorbing devices for percussive hand tools. Clark. 12401.
Starting mechanism for internal combustion engines. Lanchester. 12418.
Explosion engines Françon. 12459.
Self-centring chucks and tool holders. Donkin. 12465.
Variable speed gearing. Hansen. 12473.
Gas generators of the blast furnace type. Soc des Gazogenes Marconnet. 12479.
Safety cranking device for explosion engines. Mackenzie. 12567.
Gas producers. Roots. 12601.
Devices for regulating or controlling fluid compressors. Newton. 12610 and 12611.
Flying machines. Pippart & Noll. 12632.
Aerial machines. Curtiss. 12648.
Oil fuel burners. Brooke. 13035.
Extraction of the core keys of pipe moulds. Jagger. 13055.
Railway signalling. Tarrant & Sykes. 13125.
Stirring devices for use in roasting furnaces. De Lummen. 13551.
Charging and cooling apparatus for furnaces. Hillebrand. 13650.
Construction of floating vessels. Isherwood. 13742.
Rolling of bars or girders. Puppe. 14005.
Steam superheaters for locomotive boilers. Stirling. 14134.
Carburetters for internal combustion engines. Bond. 14297.
Grates of puddling furnaces. Hingley & Trinham. 14419.
Furnaces. Yano. 14609.
Apparatus for regulating the supply of liquid to vapour generators. British Thomson Houston Company. 15169.
Driving belt fasteners. Morris & Thornhill. 15298.
Blast furnace. Hicks. 15685.
Lathes. Walker. 16037.
Process of extracting iron and steel. Hiorth. 16275.
Casting of iron. Lester. 17227.
Pressure-regulating devices for controlling the speed of a prime mover. Herr. 17425.
Steam generators. Shepherd. 17567.
Transmission gearing for motor vehicles. Halley & Scott. 17892.
Traction vehicles. Paine. 18198.
Steam boilers. Belletti. 18841.
Transporters. Livens. 19028.
Clutches. Dallison. 19846.
Belts for pulleys. Gray. 19934.
Automatic couplings for rolling stock. Lee. 20698.
Pump bucket and piston ring packings. Clegg. 21035.
Method of increasing the calorific value of blast furnace gas. Zimmermann. 21359.
Two stroke cycle internal combustion engine. Hennig. 23261.
Piston packing Glover, Berry, & Meters, Ltd. 23924.
Apparatus for spraying liquid fuel in steam-boiler furnaces. Gruenwald. 24224.
Apparatus for covering iron pipes and bars with zinc. Krieger, Rauchfuss, & Co. 24240.
Aerial machines. Parson. 24825.
Flying machines. Kelsey. 25387.
Worm-wheel milling machines. Brown & Bostock. 25408.
Acetylene gas generators. Allen. 26087.
Blast furnaces. Kunz. 26806.
Apparatus for automatically raising liquids and compressing air. Leigh. 27354.
Balanced stop valves. Koenig. 27604.
Valve gear for steam engines. Losson. 27622.
Valves especially applicable for steam of high velocity. Koenig 29704.
Furnace grates Pellegrino & Pellegrino. 29989.

1913.

Means for putting a worm and worm wheel in and out of engagement. Rheinische Metallwaaren und Maschinenfabrik 66.
Mechanically discharging metallurgical furnaces. Franz Méguin and Co., and Müller. 494.
Compound metal plates for tanks and vats. Goold 1604.
Lubricating apparatus. Daimler-Motoren Ges. 2413.
Liquid transmission apparatus Barbey. 2784.
Cutting tools of shaping, planing, and slotting machines. Wm. Muir & Co., and Melloy. 2983
Indexing or dividing mechanism for chucks. Brown & Bostock. 3200
Airships. Lewis. 4025.
Reversing gearing for internal-combustion engines. Cernocky 4206
Crucible furnaces. Wade. 4908.
Valve gear for machines and tools operated by compressed air. Evans. 5222.
Furnace grate bars. Silva. 5461.
Treatment of dust in mines. Belger. 6343.
Ingots and ingot moulds. Gathmann. 6660.
Mechanical stoking apparatus for furnaces. Ekl. 7771.
Smoke consuming and fuel economising devices. Johns 7925
Rotary pumps and engines. Nielsen. 9222 and 9223

ELECTRICAL, 1912.

Charging storage batteries. Wilson. 9735.
Electrical heating apparatus. Matthews 12330.
Holders for incandescent electric lamps. Naylor & Nayiorgraph. Ltd. 12381.
Telephone exchange systems. Corwin. 12547.
Electric heating and cooking devices. Venner. 12569.
Electric searchlights. Pasqualini. 13680.
Automatic electric supply system. Leitner. 16174.
Electrodes for arc lamps. British Thomson-Houston Company. 18220.
Polarised telegraphic relay. Colonna. 18369.
Electric flexible conducting cords. Conner & Healey. 19807.
Wireless telegraphy. Girardeau. 24345.
Fittings for electric incandescent lamps. Pickard. 29736.

1913.

Electric arc lamps. Crompton & Co., and Crompton. 237.
Electric safety fuse plug. Weiss. 3732.

METAL QUOTATIONS.

TUESDAY, JUNE 17TH.

Aluminium ingot	95/- per cwt.
„ wire, according to sizes, &c. ......from	112/- „
„ sheets „ „ ...... „	126/- „
Antimony......£31/10/- to	£32/10/- per ton.
Brass, rolled	8¼d. per lb.
„ tubes (brazed)	10d. „
„ „ (solid drawn)	8⅞d. „
„ „ wire	7⅞d. „
Copper, Standard	£65/10/- per ton.
Iron, Cleveland	56/- „
„ Scotch	65/- „
Lead, English	£20/15/- „
„ Foreign (soft)	£20/12/6 „
Mica (in original cases), small	6d. to 3/- per lb.
„ „ „ medium	3/6 to 6/- „
„ „ „ large	7/6 to 11/- „
Quicksilver	£7/10/- per bottle.
Silver	27¼d. per oz.
Spelter	£22/12/6 per ton.
Tin, block	£205/10/- „
Tin plates	13/9 „
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Edited by
WILLIAM H. FOWLER
Wh. Sc., M Inst C E.

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Fatigue in the Steel Hulls of Ships.

THE phenomena of fatigue in metals is familiar enough to engineers who have to deal with structures containing rapidly moving pieces of mechanism subject to repetitive or alternating stresses, and engine details furnish only too many examples of its effects in the shape of sudden failures without any external evidence of weakness. Similar effects are also known, though less frequently recognised, in steam boilers and other apparatus subject to variations of pressure, where panting action combined with corrosion often sets up local furrowing or grooving. In the latter case, although breakdown may eventually result, unless relief in some shape is afforded, the development of the defect is usually slow and sufficient warning given of its existence to allow of measures being taken to prevent further development of the trouble. The existence of cracks in the skins of ships is perhaps not, a priori, an effect to be wondered at, having regard to the nature of the stresses to which they must inevitably be subject, though we imagine few people would expect their occurrence to be so pronounced as they are shown to be by facts presented in a paper by Dr. Thearle at the recent meeting of the Institute of Naval Architects. The effects in question were first drawn attention to by cracks observed in the shell plating on each side of a vessel, a short distance forward of the collision bulkhead and extending right through the plating, and a special feature in connection with them was that they were of irregular form, they did not break into rivet holes, nor were they near the edges of the plating. Soon after the occurrence of these defects was first observed, a number of other vessels came at intervals under survey affected in a similar way. The vessels ranged in size from 3,000 to 5,000 tons gross register and from two to 16 years in age, the average age being about nine years, while they included all types ranging from single deck to three deck and shelter deck to spar deck; some had web framing, while others were made with ordinary deep frames. There was

nothing, therefore, as regards type of design or framing that was unique, but all of them were of steel, though, as the material was the product of 13 different builders and seven different ports, no special brand could be regarded as the precipitating cause. Careful investigation, however, showed that the defects were the result of fatigue in the material of the margin plates due to frequent alternating pull and push stresses brought upon the plate by the heels of the frames and continued over a long period of time, and the remedy was found in giving the frame heels a better connection to the double bottom by using double instead of single angle attachments and a more extensive use of gusset plates and angles for connecting the frames to the inner bottom plating. The defects as well as the remedy will remind boiler engineers of the steps that have frequently to be taken to relieve abnormal stresses that sometimes reveal themselves in flat end plates, though it not infrequently happens that relief is sought not by imparting additional stiffness, but by according increased elasticity, especially when stresses are set up by expansion or contraction arising from variations of temperature. The study of what the late Mr. William Denny termed the "morbid anatomy of ships" is, as Dr. Thearle remarks, profitable both to the shipbuilder and the shipowner, nor are its benefits confined to them alone. There are few engineering structures that do not under certain conditions develop eccentric behaviour, and a knowledge and study of these often constitutes the basis of valuable experience.

Failures of Drying Cylinders in Textile Mills.

The Boiler Explosions Acts have happily reduced serious failures of steam apparatus in this country to a minimum by stimulating the efficiency of boiler inspection on the one hand and the sense of responsibility of steam users on the other.* This is strikingly evidenced by the comparatively trivial nature of the casualties that form the basis of the bulk of enquiries that are held and reported upon. The character of many of them is so trivial in fact that they require some little straining of language to rank them as "boiler" explosions, since they relate largely to failures of apparatus such as steam pipes, bakers' ovens, smoke tubes, &c. But failures of this kind are occasionally not without their lessons, and two explosions of drying cylinders such as are extensively used in textile and calico printing mills, referred to in a batch of reports recently issued, serve as a reminder of the risks that may be incurred by the careless working of such vessels even at low pressure. These cylinders as a rule range from 3ft. to 5ft. diam. and are made of sheet iron or copper from $\frac{1}{30}$th to $\frac{1}{20}$th of an inch in thickness, the joints being lap riveted and made tight with solder. The working pressures are usually from 8lbs. to 10lbs. on the inch, but the steam supply is nearly always obtained from boilers working at a much greater pressure and regulated by means of a reducing valve. Before the Boiler Explosions Acts came into operation failures were very frequent, and investigation showed them to be nearly always due to the absence of suitable safety appliances, especially in the shape of pressure gauges and safety valves. Everything, in fact, depended on the reducing valve being in working order, or on the attendant adjusting the steam supply. The infliction of costs by the Board of Trade Commissioners on careless owners acted as a salutary check on this neglect. Safety valves and pressure gauges were generally applied and this type of failure is now seldom heard of. It seems desirable, however, to point out to users of these drying machines that while suitable fittings may go a long way to make them foolproof, fittings alone are not sufficient. Where there is steam and moisture there is always a risk of corrosion, and where the plating is no thicker than a shilling to begin with a very slight wasting may be serious. For this reason, therefore, the interiors of these drying cylinders require inspecting at periodic intervals to ascertain their condition. Had this precaution been observed in the two failures before us, one of which resulted in serious injury, they would not have occurred.

THE TECHNICAL SOCIETY AS AN INFLUENCE IN EDUCATION.

In the course of an address delivered at the University of Illinois, Mr. Albert Reichmann, President Western Society of Engineers, said that the development of any single industry invariably resulted in the development of other industries which spring therefrom, until the ramifications were so extensive as to be almost inconceivable. For example: The advent of the steam locomotive immediately quickened development in the manufacture of iron and steel, far beyond the conception of even the most optimistic. This was followed by great activity in the development of the sciences of telegraphing, signalling, and interlocking. It also made possible and, indeed, created the conditions which were responsible for the development of modern bridges, grain elevators, and other storage plants. These, in turn, necessitated the development of industrial and commercial centres to a degree before unknown in history, and, following, or accompanying, this development of the industrial centres came the study and development of such enterprises as municipal water supply, lighting, and urban and interurban transportation.

It must further be evident that the development of these various lines of industry and commerce called for the employment of men of constructive genius. Now the ordinary artisan, with his necessarily limited education, was not capable of performing the required tasks, and it at once became apparent that to successfully cope with all the various problems entailed it was necessary that men should be especially trained, and it was this, undoubtedly, which led to the development of the technical schools; schools which furnished the means whereby the embryo engineer might form the foundation upon which to build his future success.

Engineering, however, was not an exact science. Therefore, to be proficient, an engineer must have, in addition to his theoretical training, the requisite amount of practice and experience. The training that an engineer received at a university was so broad that, to a limited degree, it enabled him to commence the practice of almost any branch of his profession. But so very broad was the field of engineering and so keen the competition in every line that if he expected to excel, an engineer must choose a comparatively narrow field in order that he might become thoroughly proficient therein. The progress of the world was so rapid, the field of human achievement so complicated, that a man must be unusually able to anywhere near keep step with the onward march of events.

An engineer must, therefore, specialise along definite or certain lines if he hoped to attain success; he must not only give the best that was in him to his immediate calling, but he must also study and observe the relation of his work to that of the other lines which had a bearing thereon. For instance, the expert in the construction and maintenance of railroad track should not only master the subject of track construction, but he must also watch the developments that were taking place in the motors and the rolling stock which passed over the road. The man who designed an engine must absolutely know the uses to which that engine was to be put. We had a notable example of this in connection with the development of the steam engine. After it was generally believed that this machine had attained its maximum efficiency it was found that it was not entirely suitable for generating electricity, and, as a result, the steam turbine was evolved.

It was very evident, therefore, that an engineer, in order to be successful, could not be a recluse. He must associate with his fellow engineers. Now he could best secure such association through the technical societies. The meeting of engineers under conditions where all were on a common footing fostered a spirit of kindly co-operation and helpfulness which bound them together and made each of greater usefulness to the other. It was only by wide co-operation that the best advancement could be made in engineering science and achievement. As in the legal profession, the decisions of the

judges were entered and published, thus forming a basis of precedent for future use, so also it was desirable that records of important engineering work should be published in order that we might benefit by the experience of others. Many of the larger engineering undertakings were the result of the co-operation of several engineers who were proficient in their respective fields. It was, of course, customary to have a chief engineer at the head of any important enterprise; nevertheless, the work which he supervised was usually the product, not of himself alone, but of those also who were associated with him. It frequently happened that on large undertakings experts in various lines of the work were employed and the duty of the chief then consisted in determining the general scope of the work, the special features being developed by these experts in their respective line. For instance, the building of a large steel plant required expert metallurgical engineers, electrical engineers, mechanical engineers, and structural engineers. It was manifest, then, that, as the work became of great magnitude, it was most important that accurate records of the same should be made available. These records could best be promulgated through the proceedings of technical societies.

Such published proceedings found their way around the world and furnished material to the universities whereby recruits might be trained to successfully solve the problems of the day. The literature published by the technical societies kept the student abreast of the times, familiarising him with the large problems with which engineers had to cope; and putting him in touch with the opinions and investigations of professional engineers who had devoted their lives to the development and progress in some special branch of engineering. The articles carefully read would be of great value to the student in solving his own problems in after life. Technical societies also afforded the younger engineers the opportunity of securing information of the experience of older engineers, resulting from the fact that they were permitted to participate on an even footing in the discussion of the papers presented.

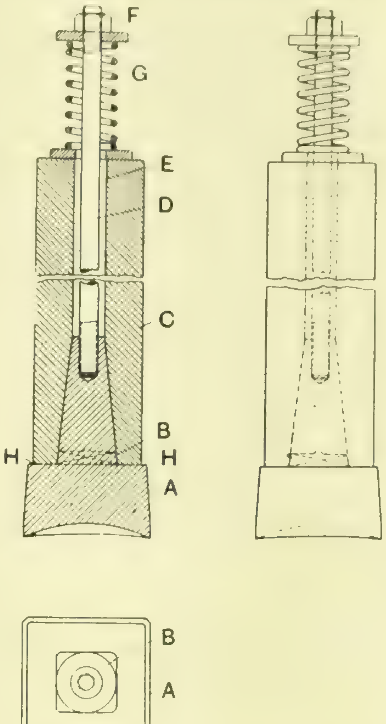
The influence of the technical society and its value to the professional engineer was probably even greater than to the student. The practising engineer was no longer under the guidance of professors and instructors and his opinions and development of ideas must be largely moulded by those with whom he associated. To be well educated involved not merely the mastery of knowledge, statistics and current events, but must also embody the broadmindedness which could see the justice and good sense of the other fellow's opinions and beliefs. A comprehensive judgment of various views and solutions was only possible through the assimilation of ideas and associations such as an engineering society offered.

In the technical societies the various steps of mechanical development were depicted both from the practical and theoretical standpoint. They afforded the engineer an opportunity to supplement his own knowledge by the experience of his fellow engineers. They afforded him the opportunity to present to the world what he himself had accomplished and to receive criticisms and suggestions from his fellow men and, resulting from the discussion of the various subjects which were presented, the engineer learned to appreciate the benefits of co-operation, by means of which both the giver and receiver were benefited.

Electrical Fatality at Blaydon.—An inquest was held in Newcastle, on the 18th inst., on F. D. Hasdell, electrician, employed by the Newcastle Electric Supply Company, who received fatal shock and burns while at work at the company's sub-power station, Blaydon Haughs, about seven weeks ago. Evidence showed that Hasdell had been making some re-adjustments to a switchboard, and at the time was at the back of the board. Earlier in the day he had explained to a superior officer how he proposed to make the re-adjustments, and had been told distinctly he must not go behind the switchboard while the current was on, but must operate from a transforming-room. He held the key which admitted him to the rear of the board, and directly contravened, not only instructions given him, but also the general regulations on the subject. While behind the board he accidentally kicked something over, and this fell upon a "live" terminal, forming a short-circuit, with the result that there was a sudden ignition, and Hasdell was shockingly burned. An assistant also sustained burns, but has since recovered.

CUTTING TOOLS OF SHAPING, PLANING, AND SLOTTING MACHINES.

IN removing internal rectangular pieces from steel forgings, such as webs of cranks or the centres of spring buckles, great difficulty has been experienced in making a self-relieving tool that will cut a groove its own width and that will cut automatically the sides of the rectangular space without re-setting the tool for each direction of traverse. The accompanying illustrations show an arrangement of cutting tool patented by Messrs. Wm. Muir & Co., Ltd., Britannia Works, Sherbourne Street, Manchester, and Mr. J. H. Melloy, designed to meet this want. The tool is rectangular in form so as to give four cutting edges which will, it is claimed, remain rigid under the heaviest cuts and yet provide a relief to whichever cutting edge is acting in order that the cutting edge may be preserved when passing back over the work on the return or idle stroke. Further, the tool presents a cutting edge that will cut a groove its own width and will automatically relieve that cutting edge on the return stroke irrespective of the side of the rectangle upon which the tool is at work. Thus a rectangular piece of metal can be completely parted from the main portion at one operation without interfering with or re-setting the tool.



CUTTING TOOL FOR SHAPING, PLANING, AND SLOTTING MACHINES.

Referring to the illustrations, A designates the cutting tool of known rectangular form so as to give four cutting edges, but formed with a projection B on its back or upper part, which fits into a corresponding tapered hole in the shank C of the tool holder. This projection B and its corresponding recess in the shank are of the shape shown or of any other suitable shape which will hold the tool rigid and prevent it from turning. A rod D is screwed into the top of the projection B and this rod passes through a hole E in the shank C and is screwed at its upper end to receive an adjusting nut F which acts to compress a spiral spring G between two washers on the rod D, the compression of the spring G acting to draw the cutting tool A up to the face H of the shank C. The tool holder is attached to the reciprocating ram or slide of the machine in any suitable manner and by any convenient means. Before commencing to cut, the spring G is adjusted to draw the projection B of the tool A into its recess in the shank C to hold it firmly in this position during the cutting stroke. On the return or idle stroke the operative cutting edge of the tool comes into contact with the work, which draws the tool A slightly away from the face of the shank C against the resistance of the spiral spring G, thus increasing its compression and permitting a small backward movement of the tool in the direction of the least resistance, namely, away from the work. It will be obvious that the effect of this relieving motion will be to prevent the destruction of the cutting edge when passing over the work on the idle stroke. The instant the tool gets clear of the work on its backward stroke the spiral spring G pulls the projection B into the recess in the shank C and thus brings and holds the tool rigidly in its true cutting position.

Memorial Statue of Lord Kelvin Unveiled. — Sir Joseph Larmor, M.P. for Cambridge University, on the 19th inst. unveiled the statue erected in the Botanic Gardens Park, Belfast, to the memory of Lord Kelvin.

BOOK REVIEWS.

The Resistance of the Air and Aviation. Experiments conducted at the Champ de Mars Laboratory by G. Eiffel, past President of la Société des Ingénieurs Civils de France. Second edition. Revised and enlarged. Translated by Jerome C. Hunsaker, Assistant Boston Naval Constructor, U.S. Navy. London: Constable & Co. 12¾in. by 10in.; 242 pp.; 27 folding plates; price, 42s. net.

This book is a record of experimental researches conducted by the eminent author at the aerodynamic laboratory at Paris specially erected by him to continue previous investigations made from the Eiffel Tower with a dropping apparatus. The experiments have entailed great expense, as well as labour, owing to the large scale on which they were made and the painstaking way in which the results were recorded. The extraordinary development of aviation during the last year or two has lent added interest to all questions on aeronautical research, and the extent to which Mons. Eiffel has been working in this field has excited considerable interest amongst the elect. Some of the main results of his experiments have been given out from time to time, and their obvious bearing on aeroplane design and progress makes the publication of the complete records specially interesting at the present stage of aviation progress. The work consists of three chapters and an appendix. Chapter I. consists mainly of a description of the laboratory and arrangements, with a complete calculation of the resistance of a plate. Chapter II. is mainly devoted to the action of air on inclined rectangular plates, the study of plates of different curvatures, as well as parallel plates and round bodies; while Chapter III. records studies made of various aeroplane wings, some designed by M. Eiffel himself and others as used on existing aeroplanes. This chapter concludes with a discussion of a method for determining the principal dimensions of an aeroplane wing and of selecting the profile to meet the conditions given in any problem. The volume is supplemented with an appendix giving the numerical results which are presented graphically in the text. The volume is one that will doubtless be highly appreciated in the small but eminently select and influential circle of engineers for whom it has been written.

* * *

Steel Rails: Their History, Properties, Strength, and Manufacture, with notes on the Principles of Rolling Stock and Track Design, by W. H. Sellew, Principal Assistant Engineer, Michigan Central Railway. 361 illustrations. London: Constable & Co. 10½in. by 8in.; 521 pp.; and 33 folding plates. Price, 52s. net.

For years considerable attention has been drawn to this subject in the States as a result of the number of rail failures that have occurred, and hence it possesses an interest to American engineers that scarcely exists amongst their British confrères. Naturally, the subject is treated mainly from the American standpoint, though it is not by any means exclusively so. Indeed, the work is the most comprehensive collation of historical facts and data at present available. A glance through its pages is sufficient to show the enormous amount of labour that must have been expended by the author in its compilation. There is scarcely an aspect of the matter which is not treated upon exhaustively, or a reliable source of information that has not been focussed upon its pages, with a view to elucidate the problems involved, whether in the process of manufacture or the subsequent behaviour of rails in practice. The matter is arranged in seven chapters, apart from copious abstracts of reports and records embodied in an appendix. The first chapter deals with the development of the present design of rail and a comparison of American practice with that prevailing in this country and on the Continent. In the following four chapters the external forces acting on the rail and the corresponding stresses produced are very fully discussed. Much information on particular defects has been written at various times, but it is widely scattered through the technical press and in the proceedings of the various engineering societies, and this is the first serious attempt to glean and analyse this information with a view to elucidating the broad principles of rail design in reference to rolling stock and track structure. The following chapter deals in detail with the manufacture of the rail in the steel works, and, without attempting a complete treatise on steel manufacture, which would be outside the scope of the work, the author deals sufficiently with the different stages of the process to enable the reader to appreciate their influence on the finished product. In the last chapter are given rail specifications representing the best modern practice and the forms recommended by the standard authorities both in America and abroad. Although the subject matter of the work is essentially a compilation, it has been made with great pains, so that the work may be regarded as the latest standard of reference.

* * *

Annual Tables of Constants and Numerical Data, Chemical, Physical, and Technological. Published under the patronage of the International Association of Societies by the International Committee nominated at the seventh Congress of Applied Chemistry, London, June, 1909. London: J. & A. Churchill. 11in. by 9½in.; 758 pp.; price, 28s. 6d. net.

This volume of tables gives in four languages, German, English, French, and Italian, the latest data respecting the physical and chemical properties of practically every element or compound that is of importance in manufacturing industry. As a work of reference it is quite unique, and the eminence of the international collaborators who are responsible for its publication are a guarantee of the accuracy of the data published.

* * *

The Theory and Practice of Mechanics, by S. E. Slocum, B.E., Ph.D., Professor of Applied Mathematics in the University of Cincinnati. London: Constable & Co. 9¼in. by 6¼in.; 438 pp.; price, 15s. net.

Of books on mechanics, both theoretical and applied, there is no end, and without detracting in any way from the merits of this one, which we may remark is well printed and illustrated and provided with carefully-selected problems and examples, we feel constrained to say it does not bring to bear any features of special novelty upon the matters discussed, which, from the nature of the subject, have to a large extent become stereotyped, while, in common with American text books, it has the disadvantage of being relatively dear, as compared with those available to British readers.

* * *

The Properties of Saturated and Superheated Ammonia Vapour, by Prof. G. A. Goodenough and Mr. W. E. Mosher. Bulletin No. 66 of the Engineering Experiment Station of the University of Illinois. London: Chapman and Hall. Price, 50 cents.

The increasing importance of mechanical refrigeration makes an accurate knowledge of the properties of refrigerating fluids extremely desirable. The experimental data on the most important of these fluids, ammonia, are meagre and somewhat discordant, and tables of the properties of ammonia that have heretofore been used are known to be quite inaccurate in many particulars. The authors of this Bulletin have analysed the available data and have worked out tables of the properties of both saturated and superheated ammonia that probably represent most accurately the present knowledge of the subject. A convenient chart, with directions for use, gives an easy means for solving graphically the usual practical problems met in refrigeration practice.

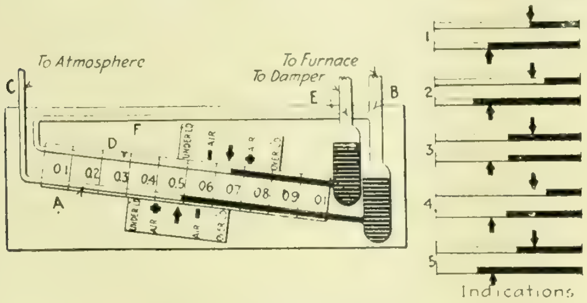
A BOILER-EFFICIENCY INDICATOR.

ONE of the difficulties in ensuring efficiency and economy of operation in large boiler plants is that of maintaining full boiler efficiency. Failure in this respect may result in excessive fuel consumption, a high degree of smoke, and irregular steam pressure. To maintain this efficiency it is necessary to keep the fireman informed as to the varying conditions, so that he may regulate his firing accordingly. While CO_2 recorders and steam-flow meters are valuable adjuncts for the operating engineer, they are expensive instruments. A device now being introduced indicates the conditions at each furnace in a graphic manner, for the guidance of the fireman. This device, described in a recent issue of "Engineering News," is shown in the accompanying cuts, and fulfils the

purposes of the CO_2 recorder, the steam-flow meter, and the draught gauge. It may be fitted with an autographic recording attachment.

The operation is based upon the relation of draught conditions to the efficiency of the boiler. The CO_2 content of the products of combustion is a good indication of the efficiency of combustion, but it gives no indication of the capacity developed by the boiler. The draught conditions, however, afford a direct indication of both efficiency and capacity. When a boiler is working at its normal capacity, a decrease in the normal draught resistance at the grate (due to a thin fire or to holes in the fire) will result in an increase in the drop of draught pressure through the boiler, and a consequent reduction in efficiency due to the excess supply of air. On the other hand, an increase in the normal resistance at the grate (due to heavy firing or failure to clean the grates) will result in a decrease in the drop of draught pressure through the boiler, and a consequent reduction in the capacity or rate of steaming. It results also in loss of furnace efficiency due to imperfect combustion.

The device mentioned above shows two things simultaneously in relation to the above conditions: (1) The draught or air pressure in the furnace; (2) the drop in draught pressure through the boiler, or between the furnace and the damper in the smoke flue. It consists essentially of a pair of draught gauges, the indicating portion being a pair of inclined tubes in which the movements of a body of



BOILER EFFICIENCY METER.

1, Normal operation of boiler; 2, too much air, fuel bed too thin, or holes in fire; 3, too little air, fuel bed too thick, or fire choked with slag; 4, boiler running with overload; 5, boiler running with underload.

oil (coloured for convenience) show the variations in draught. The construction is shown in the accompanying cut, and this part of the device is mounted in a convenient position in the boiler-room.

The lower gauge tube A has a ¼in. pipe connection B to the interior of the furnace, just above the fire level, while the pipe C, from its upper end, is open to the atmosphere. Thus the gauge A gives a direct reading of the draught or air pressure in the furnace, and shows variations in pressure due to heavy, light, or dirty fires. The upper gauge tube D is in a closed loop; its lower end is connected to a pipe E leading to a point just inside the damper at the smoke flue or uptake. Its upper end is connected by a pipe F with the furnace tube B of the other gauge. Thus the gauge D is influenced by the pressure at the furnace and at the damper, and becomes a differential gauge showing the drop in draught pressure between these points. A high reading on this gauge indicates an excessive drop, meaning an excess of air, while a low reading indicates too low a drop, which results from an insufficient supply of air. The relations of the two gauges indicate the causes of the defective conditions, some of which are indicated on the cut.

The gauges are adjusted for each boiler. While the boiler is operating under normal conditions as to steam pressure, load, and fire, the two lettered plates are shifted to bring the arrows at the positions indicated by the coloured fluids in the tubes. They are then secured in position. In firing, the aim is to maintain the coloured fluids in line with the respective arrows. This device is being introduced by W. A. Blonck and Co., Fisher Building, Chicago, and is already in use in the boiler-rooms of large office buildings and power stations, while it is being used also by the U.S. Navy Department.

More Large German Liners. — It is reported that the Norddeutscher Lloyd have ordered two liners whose dimensions are to exceed those of the "Imperator."

SUB-BITUMINOUS AND LIGNITIC COAL AS LOCOMOTIVE FUEL.*

BY SAMUEL B. FLAGG.

THE varied problem of fuel utilisation to be met and solved by large railway systems to-day, call for not only a proper anticipation of the demands for fuel and judicious purchasing of it, but also for the best design of equipment and proper methods of operation if fuel costs are to be kept down. Availability is one of the principal factors governing the cost of fuel for any road and for this reason largely some roads or divisions are using wood, others are using oil, and still others anthracite, bituminous, sub-bituminous, or lignite coals or coke. In some foreign countries peat has also been tried, but, so far as the author knows, without great success. The effort to reduce operating costs has resulted, on the one hand, in a demand for much more powerful locomotives, and, on the

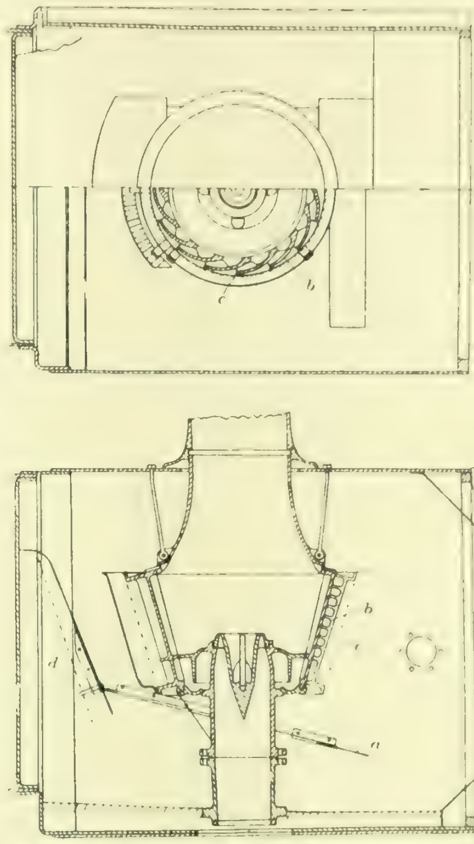


FIG. 1. FRONT-END ARRANGEMENT FOR LIGNITE-BURNING LOCOMOTIVES.

other hand, in a tendency to utilise lower grades of fuel, among which may be mentioned the lignitic and sub-bituminous coals.

Unfortunately the dividing line between lignitic and sub-bituminous coals and also between sub-bituminous and bituminous coals cannot be sharply drawn. In general, however, lignitic coals are characterised by a high moisture and high volatile matter content, by a fairly low percentage of ash, and by a low heat value. They are of a brownish colour, have a woody appearance as regards their structure, and give up their moisture and disintegrate rapidly upon exposure to the atmosphere. The lower grades of sub-bituminous coal differ from the lignites mainly in their appearance, as is indicated by the designation "black lignites" that is frequently given them. These lower grades of sub-bituminous coal, like the lignitic coals, are high in their moisture and volatile matter contents and low in heating value. Their behaviour upon exposure to the air is also similar to that of the brown lignites, but the structural resemblance to wood is much less marked, and, in many cases, is absent. The better grades of these sub-bituminous coals, on the other hand, have a much lower moisture content and a higher heat value; in fact, the heat values of some of them are considerably higher than those of many of the bituminous coals. Even these high-grade sub-bituminous fuels, however, have the same tendency

* Abstract of paper read at the convention of the International Railway Fuel Association, Chicago, May 21, 1913.

to disintegrate upon exposure to the air, and the same is true upon exposure to heat in a furnace. Another characteristic feature of both the lignitic and sub-bituminous coals is their liability to heat in the pile or bunker and to take fire spontaneously. This difficulty is experienced with many of the bituminous coals as well, but is not so uniformly encountered with such coals as with the lower grade fuels.

The tendency of both the types of low grade fuel to disintegrate upon exposure to the air has already been mentioned, and it is unnecessary to point out the desirability of keeping as low as possible the percentage of slack in locomotive fuel. Because of the disintegrating effect of heat upon these coals, however, it is especially important that the coal in the tender should contain little slack. Nearly all of the sub-bituminous coals suffer more or less seriously from breakage also, unless carefully handled in the screening and loading processes.

The question of storing such coals involves not only the slaking and the deterioration resulting therefrom, but also the

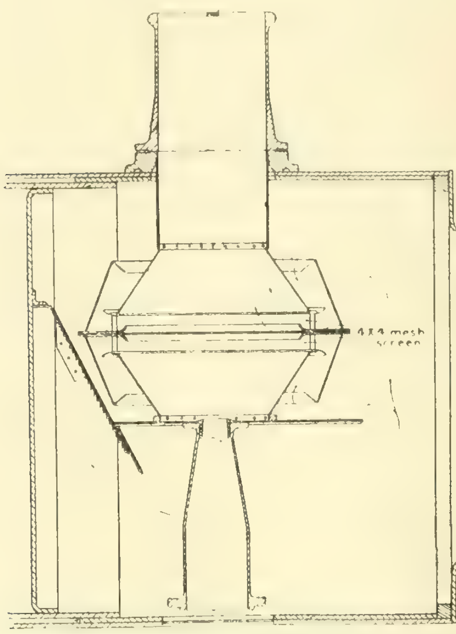


Fig. 2.—Front-end Arrangement for Lignite-burning Locomotives.

liability of spontaneous combustion. It is held by some that sub-bituminous coals can be stored for periods ranging from eight months to a year without impairing their value for locomotive use, but others state that storage for any length of time is impracticable and that the fuel must be used soon after it is mined. The author's limited experience with coals of this type leads him to the belief that they may possibly be stored for a short time without serious deterioration from the standpoint of their steaming value in locomotive use, but that the coals which are not impaired after storage for a year are more likely medium-grade bituminous coals than either sub-bituminous or lignitic. The liability of spontaneous combustion, although greater for the lignitic fuels, is considerable in the case of the sub-bituminous coals and dust or slack must not be allowed to accumulate.

The substitution of these low-grade coals for bituminous fuel introduces, in addition to the difficulties already mentioned, a number of problems of operation. Because of the generally lower heat value and the difficulty of realising this value in the firebox, it is obvious that a much larger quantity of coal must be burned in a given time in order to develop the required horse-power. For this reason the grate area must be greater—one authority says 50 per cent. greater—than would be required for good bituminous coal. The disintegrating action of the heat further complicates matters by increasing the resistance of the fuel bed to the flow of air through it. High draughts are necessary in order to overcome this resistance and maintain the required rates of combustion, and to get them the exhaust pressures must be increased to such an extent that the efficiency of the locomotive is reduced 5 to 10 per cent. thereby. One point in favour of these sub-bituminous coals that should not be overlooked is the freedom from clinker troubles. The percentage of earthy matter in them is usually low, in many instances under 5 per cent., and the sulphur content is also low. If the refuse has any clinkering tendency at all, the clinker is of such a nature that it is easily broken up and therefore introduces no serious operating difficulties.

In some sections the greatest problem connected with the use of sub-bituminous fuels has been the one of preventing spark troubles. Because of the high draughts necessary for burning these coals and on account of the absence of any caking properties of the fuels, large quantities of sparks are carried out of the firebox. These sparks must either be caught by some arrangement of screens or so delayed in passing out that they are cooled down to a temperature at which they will do no harm, or they must be broken up into particles of such small size that they will be dead before reaching the ground. The first attempts to solve this problem were made with different sizes and arrangements of screens and usually included two screens for the gases to pass through. It was usually found, however, that one of the screens clogged and prevented the free steaming of the engine. By using a single screen properly set most of the clogging trouble can be done away unless there is a steam leak in the smokebox or wet slack coal is being used, and some roads claim to have found the screen as satisfactory and effective as any means for eliminating spark troubles. Screens set horizontally will, with some forms of stacks, remain clear longer and give less trouble than if set on an incline, and likewise small mesh netting of small wire is more satisfactory than small mesh netting made of large wire. In using these small mesh screens in locomotives burning sub-bituminous coals it is very important that no holes be left around the edges of the screen or where it comes in contact with steam pipes, as any holes of this sort will give serious trouble. The front ends should be so arranged that they may be readily inspected and cleaned, and it is of the greatest importance that inspections be frequently and thoroughly made.

A front-end arrangement designed to reduce in size the sparks or cinders and also delay their delivery from the stack is shown in Fig. 1, patents on which are held by the American Locomotive Company. On the western lines of one road a number of locomotives have been equipped with this device, and it is stated that the sparks are reduced to such small size that they give no trouble. Some of the engines so equipped have been in service as long as four years and others for over two years, and during this time no fires have been set out by sparks from them, although they are operated on the most dangerous divisions of the line. The sparks upon leaving the front end of the flues strike the baffle plate *d*, and are deflected downwards. In front of the baffle plate is a table plate with an adjustable end *a*, under which the sparks and gases pass. Deflector plates attached to the boiler front and to the top and bottom of the smoke arch and a flat plate attached to the front end door again deflect the gases and solid particles, after which they pass through a 4 by 4 mesh netting *c*, which surrounds the gyrus vanes *b*. These vanes are separate castings attached to the bottom end of a bell-shaped casting suspended from the base of the stack and set with about a 2in. opening between them. In passing between these vanes the particles are further pulverised and by the time they leave the stack are harmless.

Another front-end arrangement for sub-bituminous coal burners is shown in Fig. 2. This device was designed by one of the engineers of a western road. With this arrangement the sparks do not pass through any screens or netting, the success of the device depending rather upon the delayed delivery of the solid particles, thus allowing them time to cool down. A roughened plate of ¼in. steel is attached to the regular baffle plate at the front flue sheet and this, together with the table plate, fastened to a flange on the upper end of the exhaust pipe, deflect the sparks and gases, causing them to pass to the front of the smokebox. A liner plate attached to the front-end door serves as another deflecting plate. From this point the paths of the sparks and gases are indicated by the direction lines and arrows. The top and bottom sides of the plate midway between the two petticoat pipes are faced with 4 by 4 mesh No. 8 netting shaped as shown in the illustration. Sparks in passing between the housing surrounding the petticoat pipes and entering the latter, strike these screens and are broken up into smaller particles before being discharged out of the stack. It is stated that this device will absolutely control the giving off of sparks, floaters, or fires of any description.

BROWN'S WORM WHEEL GENERATING MACHINE.

WE illustrate herewith a design of worm wheel generating machine, the invention of Messrs. David Brown & Sons (Huddersfield), Ltd., Park Gear Works, Lockwood, Huddersfield, in which means are provided whereby the table can be disconnected from its drive at will and rotated freely by hand in order to test the truth of the work to be cut and also to admit of adjustment of the wheel blank relatively to the hobbing cutter to cause this cutter to operate on different teeth.

Fig. 1 is a plan view of the work supporting and driving portion of the machine; Fig. 2 is a sectional elevation taken on the line A A, Fig. 1; Fig. 3 is a front view of the table driving device, disconnected; and Fig. 4 is an end view of Fig. 3, looking in the direction of the arrow B. The table C has a depending cylindrical portion which is mounted in a long parallel bearing. Near its upper end the frame is provided with a conical bearing on which rests a corresponding conical portion on the table. These parallel and conical bearings support the table rigidly, the downward thrust during cutting being taken by the conical bearing. Formed integral with the table C is a worm wheel D whose diameter

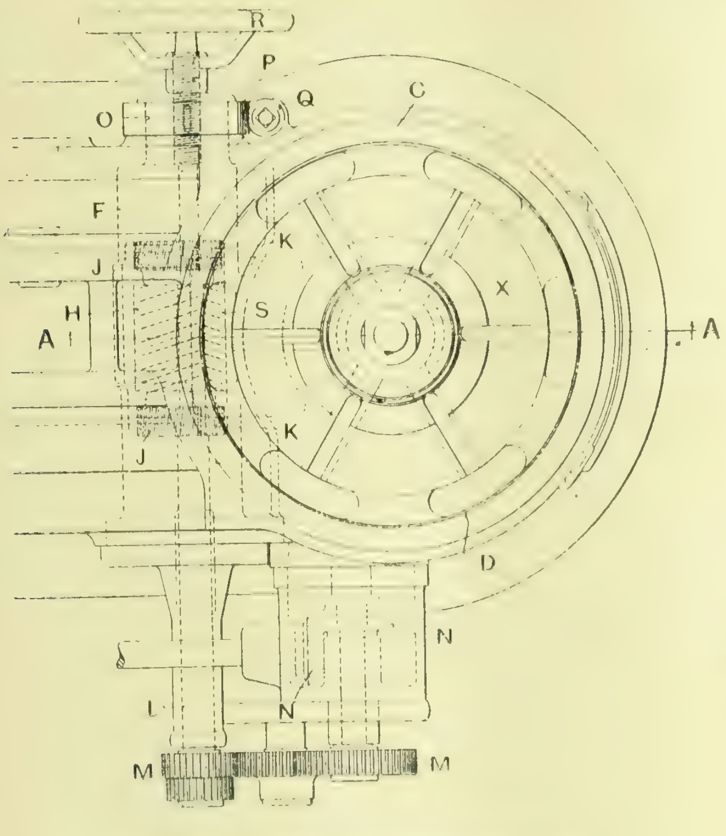


FIG. 1.—BROWN'S WORM WHEEL GENERATING MACHINE.

is approximately twice the diameter of the largest wheel that can be cut on the machine, whereby great accuracy is ensured when the machine is cutting at its maximum capacity. In the upper portion of the table are formed a series of slots which admit of the cuttings from the work falling or being forced through them through a cavity E into a receiver, from which they can be removed from time to time. A sieve or reticulated false bottom allows the lubricant, supplied during the cutting operation, to drain from the cuttings into a well from which it can be returned through an outlet to the pump well for re-use, or the said lubricant may be drawn off, as desired, by the drain cock shown.

Supported in suitable bearings is a cradle F in which is journalled a spindle G (Fig. 3) having fast thereon a worm H adapted to mesh with and drive the worm wheel D on the table. Also fast on the spindle G are spiral wheels J which respectively mesh with spiral wheels K fast on a shaft L extending within the lower part of the cradle. This shaft is driven by change gearing M and bevel wheels N from the main driving shaft of the machine. Fast on the boss O of the cradle is a partially toothed wheel or toothed segment P with the teeth of which meshes a worm Q fast on a spindle supported in a vertical bearing. By rotation of the worm Q, the spindle of which is provided with a hand wheel, the cradle F can be rocked or turned about its pivotal centre, which is that of the shaft L, and by reason of the eccentric disposition of the spindle G carrying the worm H, this worm will be disengaged from the worm wheel D on the table and the latter thus be left free to be rotated by hand. In order to lock the mechanism, when the cradle has been turned or rocked to cause the worm H to mesh with the worm wheel D, a hand

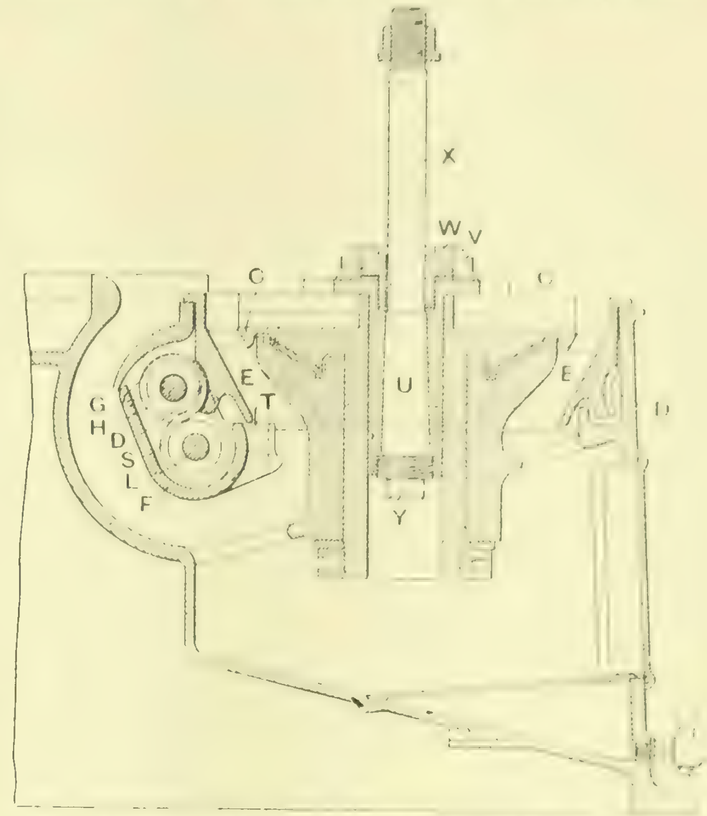
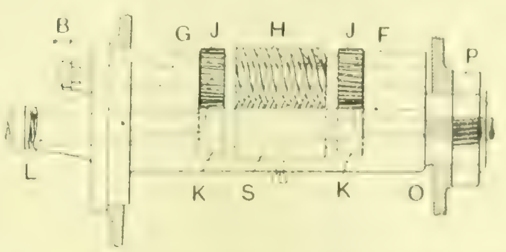


FIG. 2.—BROWN'S WORM WHEEL GENERATING MACHINE.

wheel R is provided whose boss works on a screw carried by the cradle, rotation of the hand wheel in one direction forcing a locking collar against the worm or segment wheel P and pressing the opposite face of this wheel against a facing on the framework. A projection on the cradle is adapted to abut against a part of the framework to limit the inward movement of the worm H. This arrangement for enabling the work table to be disengaged is of considerable advantage, and enables the operator to freely revolve the table whenever desired, to test the truth of the work being cut, or to adjust the work relatively to the cutter in order to present fresh or uncut spaces in the work opposite the teeth of the cutter.

The worm H meshes with a worm S, mounted on the shaft



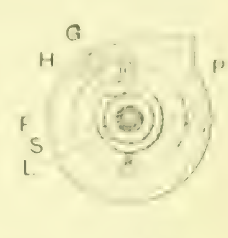


FIG. 3. FIG. 4.
BROWN'S WORM WHEEL GENERATING MACHINE.

L and running in an oil bath formed in the cradle F, the worm S automatically conveying lubricant from the bath and applying it to the tooth surface of the driving worm. An annular channel T formed on the inner walls of the framework beneath the worm wheel D, as shown at Fig. 2, receives any lubricant which may drop from the worm wheel and conveys it back to pockets in the cradle F, from which it finds its way back through openings into the oil bath. Shields or guards prevent the entry into the oil bath and annular channel T of any metal cuttings or foreign bodies.

A sleeve U, extending down within the depending portion of the table and provided at its upper end with a flange adapted to be bolted to the table, receives at its upper end a micrometer screwed adjusting nut V and bush W, the latter being provided with a keyway to slide on a key carried by the work spindle X, the latter being made conical at its lower end and being secured in a correspondingly shaped opening in the sleeve by a screwed plug Y. The blank to be cut is secured on the spindle X and rests upon the top of the bush W, whose adjustment relatively to the sleeve U enables the vertical height of the blank to be adjusted to position it accurately with respect to the cutter. By this means the table can be run at such a speed that the maximum advantage of a high-speed cutter can be utilised, whereas at present the cutter cannot in many cases be run at its maximum speed owing to the construction of the work table and its operating mechanism.

ALLOYING OF ALUMINIUM.*

BY C. H. IVINSON.

It is generally admitted that pure commercial aluminium is entirely unsuited for most engineering purposes, owing to the fact that it is too soft, has little mechanical strength, is rather difficult to cast, and does not lend itself to easy working. In general engineering work the alloys of aluminium are much more important than the pure metal; but the indiscriminate use of metals to form aluminium alloys has given the latter metal a bad reputation. Aluminium alloys with every known metallic element, accompanied by disengagement of heat, and is particularly active in combining with copper. Most of the alloys are chemical combinations of the metal, rather than mechanical mixtures, the alloys with lead, antimony, and mercury being exceptions, as these metals do not alloy very easily with aluminium.

The useful alloys of aluminium seem to fall in three groups, viz.: (1) Aluminium containing not more than 10 to 25 per cent. of added metals. (2) Metals containing not more than 10 to 15 per cent. of aluminium. (3) Alloys of rare metals with aluminium containing from 0·5 to 5 per cent. of added metal.

In order to make aluminium harder, stronger, and of better wearing properties, at the same time keeping its valuable lightness and beautiful colour, it is alloyed with small percentages of such suitable metals as manganese, zinc, tin, copper-nickel, &c. It has been the writer's privilege to alloy aluminium with almost every metallic element, some of the resultant alloys being only curiosities, the cost of production making them of no commercial value.

For the purpose of the present paper the writer will first briefly deal with the commoner alloys, the best known being an alloy of copper and aluminium containing from 4 to 10 per cent. of copper, and the aluminium-zinc alloys containing from 8 to 30 per cent. zinc. Zinc is the cheapest known hardener of aluminium, and in quantities of up to 15 per cent. combines to increase the rigidity and strength of the aluminium. Tin when alloyed alone with aluminium appears to develop brittleness, and alloys of 15 per cent. of tin and aluminium have been known to entirely disintegrate in the course of a few days. Nickel added by itself to aluminium produces unstable alloys. An alloy of 4 per cent. nickel has been shown to disintegrate in a very short space of time after being cast, but the introduction of a third element such as copper is an advantage. Phosphide of copper added in quantities of 1½ per cent. to a zinc-aluminium alloy containing from 12½ to 15 per cent. zinc gives fluidity to the molten metal. Phosphide of zinc containing 25 per cent. phosphorus may be substituted in the proportion of 0·05 per cent. This is one of the best fluxing and cleansing agents the writer knows for all aluminium alloys, and should be added to the molten alloy for a few minutes before pouring by wrapping in paper and plunging to the bottom of the crucible by means of tongs and stirring briskly.

Magnesium-aluminium alloys containing 1 to 10 per cent. magnesium are much improved by the addition of 5 per cent. zinc, as this addition imparts better wearing properties to the metal and aids in producing homogeneous castings. By the addition of 1 per cent. phosphide of copper less oxidation of the metal takes place during the melting operations.

A few notes on the behaviour of the alloys of copper, nickel, magnesium, and zinc may be appreciated. All these alloys have good tensile strength when newly made, but in the course of time chemical and electrolytic actions render some of them very brittle, and in a good many cases lead to the entire disintegration of the alloy, especially if iron, sodium, and silicon are in the metals as impurities. Aluminium is very liable to take up silicon from the crucible, especially if overheated. It is most important that these alloys should be melted without fluxes—fluxes such as mixtures of sodium and potassium chloride. Zinc chloride acts on the crucible, thereby causing the aluminium to wet the sides of the crucible and dissolve out the silica which in the presence of moisture liberates silicon hydride, which, in time, causes the entire disintegration of the alloy. Too much stress cannot be put upon the fact that the metal must be melted at as low a temperature as possible, namely, a temperature which will cause the metal to become fluid. Aluminium absorbs sulphur at a bright red heat, and the gas is liberated when the metal is poured into the moulds, causing porous and "blow-holey" castings. Aluminium alloys should always be melted in crucibles having good tight-fitting lids to prevent, to some extent, the absorption of sulphur from the fuel being used. Aluminium when heated to too high a temperature also absorbs nitrogen and hydro-carbons. The writer has found a small piece of potassium nitrate (an egg-spoonful to 100lbs. of metal) wrapped in filter paper, to be the best means of removing these occluded gases. A brisk reaction takes place which expels these occluded gases. After the reaction has ceased the metal is poured at as low a temperature as possible, the pouring temperature affecting the tensile strength in a very marked degree.

After numerous tests the writer is of the opinion that silicon and sulphur are two of the deadly enemies of aluminium alloys, especially when the metal is overheated. One of the best types of furnaces the writer has found, after a great many trials, for melting aluminium and its alloys is a furnace which uses gas and air under pressure, which is blown in by means of a Leimans' blower. Such a furnace is made by Messrs. Fletcher, Russell, & Co., Ltd., of Warrington, and is ideal for melting metal, especially if fitted with a tilting device. The pressure used on the blower is 4lbs. to 6lbs. per square inch.

It is always advisable when making up an alloy of aluminium to make a concentrate of the metal which is to be alloyed with the aluminium, *i.e.*, to first make, say, a 20 or 25 per cent. concentrate metal and add this in the proper proportions to the molten aluminium.

During the last few years metallurgists have been experimenting with some of the rarer metals, and this part of the subject is most interesting. The writer has personally alloyed aluminium, as previously stated, with almost all the rarer metallic elements, such as cerium, neodymium, lanthanum, tantalum, zirconium, and beryllium, and some of these alloys gave most remarkable results even in quantities of only 1 per cent. and under. Cerium and beryllium are particularly interesting, 0·5 per cent. of cerium exerting a most wonderful effect on the aluminium, raising the tensile strength of the metal from 4·5 tons per square inch to 10·3 tons per square inch, and giving an elongation of 8·5 per cent. on 2in. The *modus operandi* is to reduce the fluoride of cerium. This alloy was placed in sea water and boiled for 60 hours; the sample was carefully weighed before and after the boiling process, and it was found that the metal was the same weight as before being experimented upon. One side of the metal was polished and after the boiling it was found to be untarnished.

Another interesting alloy is one of beryllium or glucinum. An alloy of 2 per cent. beryllium gave a tensile strength of 11·8 tons per square inch with an elongation of 10 per cent. on 2in. It was of a beautiful silver-white colour, and could be hammered out cold into leaf; it also withstood the action of sea water perfectly. This alloy was made by the reduction of beryllium fluoride.

A good many experiments have been made during the past two or three years with alloys of manganese, titanium, chromium, molybdenum, tungsten, &c., and a few notes may be here given on the behaviour of these metals when alloyed with aluminium. They form a very interesting series of alloys, either when alloyed by themselves or in the presence of copper. Titanium and chromium alloys are both affected by sea water and ordinary atmospheric conditions. The former alloy, when polished in the presence of sea water, develops white spots on the metal which, when removed, show deep pit

* Paper presented at the annual convention of the British Foundrymen's Association, June 21st to 24th, 1913.

marks on the surface of the metal; and the same remarks apply to the alloys of chromium. Two methods have been employed to manufacture these two alloys: (1) The reduction of titanium and chromium oxide in a magnesite-lined crucible by means of powdered aluminium; (2) the reduction of the oxide of the metals by molten aluminium, using cryolite and potassium chloride as fluxes. The *modus operandi* is first to melt the cryolite in the crucible and dissolve the oxide of the metal in the molten cryolite and adding to the same molten aluminium, when a complete reduction of the titanium and chromium takes place. Calculating the amount of metallic titanium required, $3\ Ti\ O_2 + 4\ Al.\ \ 3\ Ti + 2Al_2O_3$. These metals give very rigid and hard alloys. The tensile strength of the one containing 2 per cent. of metallic titanium was 10·4 tons per square inch, and the elongation 4·5 per cent. on 2in. The alloy with chromium, containing 1·5 per cent. metallic chromium, had a tensile strength of 9·34 tons per square inch, with elongation of 2½ per cent. on 2in. But the behaviour of these alloys in resisting atmospheric conditions was far from satisfactory.

Tungsten has been recommended as being a suitable metal to alloy with aluminium to resist corrosion, but in the hands of the writer this has not proved very satisfactory. An alloy containing 2 per cent. copper and 0·5 per cent. tungsten rapidly disintegrated under ordinary atmospheric conditions. At least 100 different samples of this alloy were prepared in the varying proportions of 0·2 to 5 per cent. pure tungsten alloyed by itself with the aluminium, and also in conjunction with nickel, manganese, copper, &c. The results of some of these were disappointing. The alloy of zinc and nickel containing 3 per cent. nickel and 0·75 per cent. zirconium gave extraordinary results as far as tensile strength was concerned, having 12·2 tons per square inch, with elongation 9 per cent. on 2in. Its behaviour in sea water was very extraordinary; it was boiled for 72 hours in sea water, and when tested, after the boiling process, it only showed 4 tons per square inch tensile strength; its fracture was very crystalline, and it was also very brittle.

Zirconium 0·75 per cent., when alloyed with aluminium without the presence of nickel, gave the same tensile strength after the boiling process as before, namely, 9·3 tons per square inch. Molybdenum when alloyed with aluminium had the opposite result. An alloy was made containing 1·5 per cent. molybdenum with aluminium which, after being boiled in salt water, gave a lower tensile strength than before the boiling; but when the molybdenum was alloyed with the aluminium in the presence of copper in the proportions of molybdenum 1·5 per cent., and copper 1·5 per cent., the tensile strength of the metal after the boiling process was the same as originally. This makes the theoretical alloying of aluminium a very fascinating subject, as it is almost impossible to theorise or to account for the peculiar behaviour of these different elements when combined alone or in conjunction with another in aluminium. Within recent years several alloys have been put on the market for which sea water resisting properties and resistance to ordinary atmospheric influences are claimed. It is no doubt working on the above lines that such alloys have been made possible. The only drawback of the rare elements is their prohibitive costs, but it is to be hoped that chemists and metallurgists will go on experimenting to produce these rare elements at a commercial price; and no doubt a lot has been done in this direction since the advent of the Goldschmidt process for the reduction of the rarer metals from their oxides by means of powdered aluminium.

There is no doubt that aluminium has obtained its bad reputation through the unscientific mixing of metals, and the compositions of some of the most successful alloys which withstand the action of sea water are rigidly guarded as secrets. Aluminium was boomed too greatly some years back; it was put forward as being the cure-all for blow-holes in brass, iron, and steel, also for promoting the fluidity of zinc for galvanising processes, &c. In the writer's opinion aluminium ought to be added very sparingly to brass, especially if the latter has to be remelted several times, as on each re-melting the aluminium oxidises, rendering the brass porous and reducing greatly its mechanical strength. The same applies to steel; the aluminium ought to be added extremely sparingly. For steel it is better added as a titanium-aluminium alloy and for the brass as a manganese-aluminium or titanium-aluminium alloy; for titanium and manganese seem to counteract the evil effects of the aluminium. The writer has used an alloy of 50 per cent titanium and 50 per cent aluminium with very good results, whereas, when the aluminium was used alone, very defective castings resulted.

WEIGHT OF SOLID METAL SPHERES OF VARIOUS DIAMETERS.

BY R. BERRY.

In the many engineering text books one frequently meets with tables showing weight in pounds per lineal foot run of metal bars, both round and square, also in the sheet, but rarely does one meet with a table showing weight in pounds per inch diameter of spheres or balls composed of the different kinds of metal. Quite recently, whilst carrying out experiments, the writer had occasion to use different-sized balls of various metals, where weight of same played a most important part, and it may be of interest to many of your readers to have some simple method of calculating weights of various sized spheres, also tables, showing at a glance weights of different sizes composed of metals mostly in use.

It may not be generally known that surface or area of a sphere is just equal to the area of a cylinder, whose length and diameter = diameter of sphere. As an instance, the area of a cylinder 10in. diam. x 10in. long will be length x diam. $\times \pi$ or $10 \times 10 \times 3{\cdot}14 = 314$ sq. in., and this will also be the area of a sphere 10in. diam.

Hence it is stated $D^2 \times \pi =$ area of sphere.

$$\text{Now, } \frac{D^3 \times \pi}{6} = \text{contents in cubic inches.}$$

It is remarkable to note that the number of cubic inches of copper per pound weight is just equal to the value of π. Therefore, a very simple yet useful formula for calculating weight of solid copper spheres is

$$\frac{D^3 \times 3{\cdot}14}{6 \times 3{\cdot}14} \text{ or } \frac{D^3}{6} = \text{lbs. weight for copper.}$$

A more general formula for any solid sphere is

$$\frac{D^3 \times \text{spec. grav. of any solid}}{6 \times \text{spec. grav. of copper}} = \text{lbs. weight}$$

and from the above a table of weights has been compiled.

This gives the weight when diameter is known. If, on the other hand, weight was known and diameter required, then the inverse would be

$$\sqrt[3]{\frac{6 \times \text{spec. grav. of copper} \times \text{lbs.}}{\text{spec. grav. of any solid}}} = \text{diameter in inches.}$$

Table showing Weights of Solid Metal Spheres taken from the "Berry" Formula.

$$\frac{D^3 \times \text{spec. grav. of any solid}}{6 \times \text{spec. grav. of copper}}$$

Dia. in ins.	Area in square inches.	Weight in lbs.					
		Steel.	Wrought iron.	Cast iron.	Copper.	Brass.	Lead.
1	3·14	·146	·142	·134	·166	·155	·213
1½	7	·495	·481	·456	·563	·526	·723
2	12·56	1·13	1·1	1·07	1·33	1·25	1·71
2½	19	2·26	2·2	2·1	2·6	2·4	3·3
3	28·3	3·9	3·8	3·6	4·5	4·2	5·8
3½	38	6·2	6·1	5·8	7·146	6·7	9·2
4	50·2	9·27	9	8·6	10·6	9·9	13·6
4½	63	13·3	13	12·3	15·2	14·2	19·5
5	68·5	18·5	18	17	21	19·5	27
5½	94	24·4	23·7	22·6	27·7	25·9	35·5
6	113	31·9	31	29·1	36	33·6	46
6½	132	40	39	36	45·7	42·7	58·7
7	154	50·5	49	46·2	57	53·3	73
7½	176	62	60·2	57	70·3	65·7	90·3
8	201	75·2	73	69	85	79·4	109
8½	226	90	87·5	83	102·3	95·6	131·4
9	254	107	104	98·1	121	113	155
9½	283	126	122·4	116	143	133·6	183·7
10	314	146	142	134·5	166	155	213
10½	346	169	165	156·5	193	180	284
11	380	195	190	180	222	207·5	286
11½	415	222	216·5	205	253	236·4	325
12	452	254	247	233·5	288	278	370

TRIALS OF THREE FERRY STEAMERS PROPELLED BY GEARED TURBINES.*

BY J. INGLIS, LL.D.

THE following paper is offered in response to a suggestion from Dr. Archibald Denny during the discussion on Sir Charles Parsons' paper read at the spring meetings. Dr. Denny expressed a wish to have the results of the trials of three small vessels fitted with geared turbines, but, at that time, these trials were incomplete. The vessels are named "Curzon," "Elgin," and "Hardinge," after three Viceroys of India, and are intended to connect Ceylon with the Indian mainland by a short sea passage in smooth water instead of the long and occasionally disagreeable voyage which hitherto has been the only available means of transit.

The South Indian Railway Company, owners of the vessels, applied for guidance to the late Sir William H. White, who

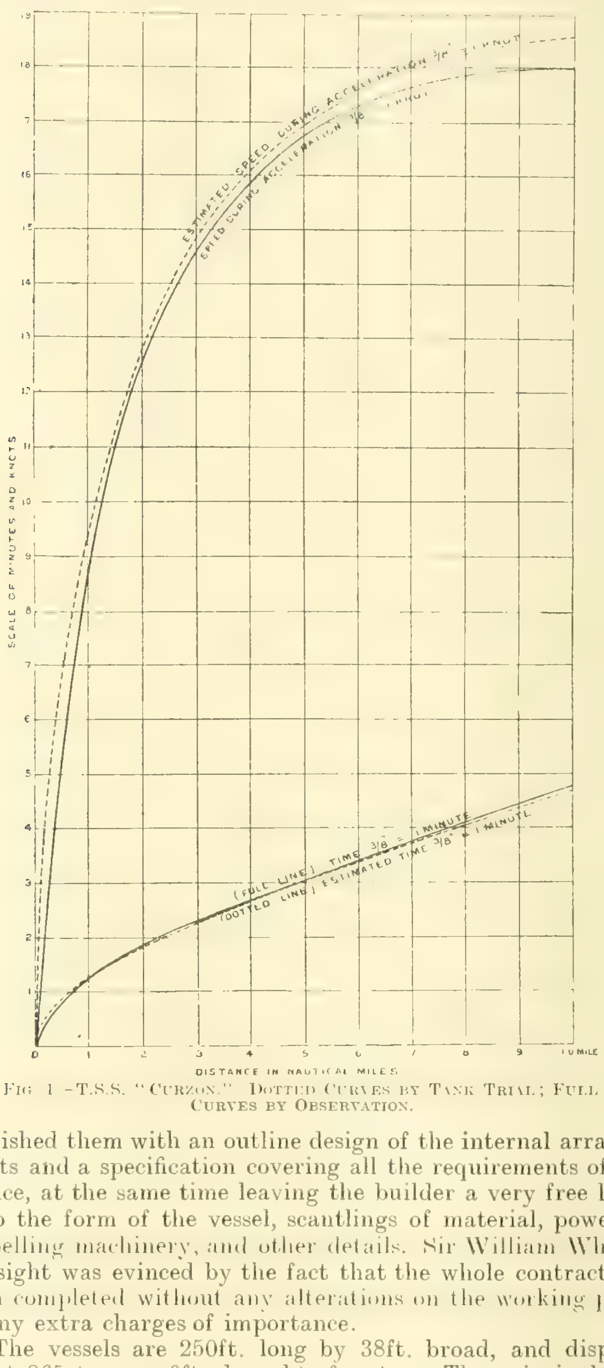


FIG. 1.—T.S.S. "CURZON." DOTTED CURVES BY TANK TRIAL; FULL CURVES BY OBSERVATION.

furnished them with an outline design of the internal arrangements and a specification covering all the requirements of the service, at the same time leaving the builder a very free hand as to the form of the vessel, scantlings of material, power of propelling machinery, and other details. Sir William White's foresight was evinced by the fact that the whole contract has been completed without any alterations on the working plans or any extra charges of importance.

The vessels are 250ft. long by 38ft. broad, and displace about 865 tons on 6ft. draught of water. The principal conditions of the contract were that the vessels should carry 160 tons of dead weight on a draught of water not exceeding 6ft., and, while so loaded, be capable of steaming 20 sea miles at the rate of 16½ knots, starting from rest, no allowance being made for the time occupied in getting under way. The fuel used on trials was to be as nearly as possible equivalent in heating power to the Indian coal available on service, a sample analysis being furnished which showed 63·26 per cent. of fixed carbon. The coal actually used contained 63·86 per cent. of fixed carbon, being a rather poor sample of Scotch coal, but almost exactly what was wanted. Yarrow boilers were fitted, the heating surface being 7,000 sq. ft., and the grate 168 sq. ft. The boilers were arranged to be fired with oil if that should be found advantageous. It will be observed that the actual full speed to be attained was not stated in the conditions, nor were any data available whereby it might be computed. It was considered safe to assume 17 knots, and estimates were made on that basis, as, if 17 knots could be maintained for 19 miles, there would be left one mile of distance and over five minutes of time to attain full speed. This was deemed to be sufficient.

* Paper read at the Summer Meetings of the Fifty-fourth Session of the Institution of Naval Architects, June, 1913.

A preliminary trial of the "Curzon" was made, on December 10th last, to test the working of the turbines, and, the weather being very calm, advantage was taken of the divisions on the measured mile in the Gareloch to learn something about the acceleration of a vessel starting from rest. The results are shown on the diagrams. Diagram (Fig. 1) shows, on a base of one nautical mile, the time for each fraction of a mile and the increasing speed during acceleration. Diagram (Fig. 2) shows, on a base of speed in nautical miles per hour, the revolutions of propellers, the slip in knots and the slip per cent. during acceleration. Diagram (Fig. 3) shows the revolutions, slip and shaft horse-power during a progressive trial of the "Elgin," also the effective horse-power (which Messrs. Denny were so kind as to ascertain for us in their experimental tank), and the ratio of effective to shaft horse-power.

The dotted curves on Fig. 1 show the computed speed during acceleration, also the time required to run one mile starting from rest. These were constructed by Mr. Mumford, superintendent at Messrs. Denny's experimental tank, from calculations based on the resistance of the model. The agreement between the curves constructed from calculations made on a model and those from experiment on a full-sized ship is extremely close. If Mr. Mumford is present I hope he will tell us how this clever piece of work was done.

The 20 miles distance, starting from rest, was steamed by the "Curzon" in 65 minutes, equal to a mean speed of 18·46 knots, the tide being with her for the first half and against her for the second half, the wind fresh, about three points abaft the beam. The time occupied by the "Hardinge" was 66½ minutes, equal to 18·045 knots, she having a stiff breeze against her and a weak tide in her favour, high water at Greenock being about 8 o'clock on that day.

It was not considered necessary to repeat this trial with the third vessel, and instead of this a progressive trial was made on the measured mile, and a run of two hours at high speed was utilised in measuring the water consumption. During the latter the revolutions were somewhat reduced by a strong head wind, the average being 482·8 per minute, corresponding to a speed of 17·8 knots. The mean shaft horse-power was 2,390 and the consumption of steam, for turbines only, 12·55lbs. per hour per shaft horse-power.

The consumption of steam by the auxiliaries amounted to nearly 3lbs. per hour per shaft horse-power of main engines. Among the auxiliaries are reckoned the engine driving a large dynamo, and the steam steering gear. The temperature of the feed was 205° Fah. The air pressure in the stokehold did not exceed a quarter of an inch of water column.

An attempt was made to record the noise of the gearing on a new phonograph obtained for the purpose, but although the sound of the engine-room telegraph gong and some vocal efforts were clearly rendered by the instrument, the sound of the gearing could not be recognised amidst the scraping of the reproducer on the wax cylinder.

Prof. Biles, in his interesting remarks on Sir Charles Parsons' paper, quotes a shipowning friend repelling the suggestion to permit the innovation of "cog-wheels" in a passenger steamer's propelling machinery. The use of cog wheels cannot be regarded as a novelty even in high-class ocean going passenger steamers. I can remember the building, in 1855, of the steamer "Oneida," which was then deemed large, seeing that only 25 steamers of the same or greater register tonnage were on the Mercantile Navy List at that date. This vessel was 307ft. long by 39ft. beam. Her gross tonnage was 2,284, and her net register 1,372 tons.

Her engines were direct-acting, but the results were so unsatisfactory that, before she was two years old, that is in 1857, she was put into our hands to undergo certain alterations and receive new geared engines of about 3,000 h.p. These engines,

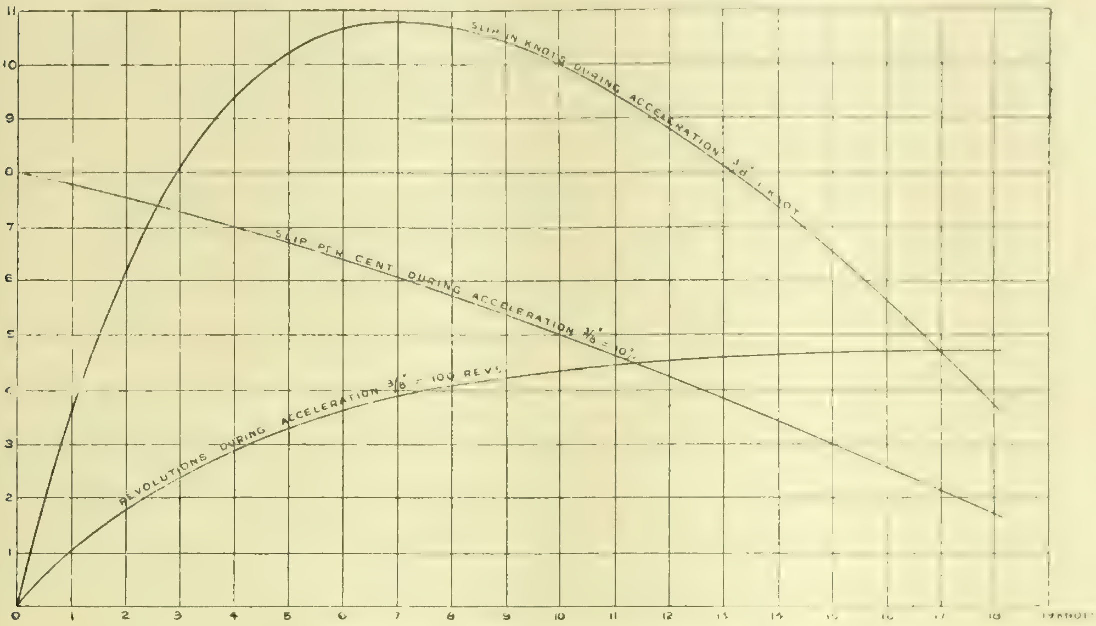


FIG. 2. T.S.S. "CURZON" CURVES ON SPEED BASE.

cog wheels and all, appeared to work satisfactorily for 17 years, though I fear they could not have been remarkable for economy of steam, and in 1875 she was converted into a sailing ship. Thirty years later, being then 50 years old, she disappeared from the British register, having found a new owner in Chili.

High speed of piston being somewhat of a bugbear to engineers in the 'fifties, geared engines were common enough in channel and coasting steamers, and even Robertson's frictional gearing, where the wheels and pinions had grooves in place of teeth, was not unknown in marine work. What was tolerated 60 years ago, with cast-iron pinions and mortise wheels, might surely be adopted now with the refined methods of gear-cutting which Sir Charles Parsons and others have made available.

PRIME MOVERS FOR ELECTRIC POWER.

A SHORT paper on the above subject was read by Dr. S. Z. de Ferranti, at the 18th annual convention of the Incorporated Municipal Electrical Association, held in London during the past week. He remarked that, notwithstanding the amount that had been written regarding the different systems of driving electric generators, the subject still seemed to be one of considerable interest. The position to-day was that the steam turbine was in possession of the field, and that gas and oil engines were looked upon as likely alternatives. Many people believed that it was only prejudice or the fear of doing something new that prevented engineers from using these two latter methods for generating their power. The author, however, did not agree with this view, and believed that engineers were using the only means that were at present economically available for the work they had to do. Electricity was being produced on a larger scale every day, and it appeared certain that to obtain the full benefits of electric working the current must be produced in large stations supplying extensive areas embracing all classes of demand.

Considering the question from the point of view of the comparatively large generating station, he observed that the essential qualities of a power-producing plant were reliability and low cost as regards capital running and maintenance. The question might be considered in detail under the following headings: Nature of fuel consumed, its availability and cost; amount of fuel consumed per unit generated; stand-by losses; labour involved in running; cost of upkeep of plant; capital cost of plant; size of units, simplicity or complication; and reliability and proved capacity for work required. As we were a coal-producing country it was evident that coal was our natural fuel. The very fact of oil being so sought after as fuel for certain purposes put it out of the question for general power production. In the first place, the automobile on land must consume, and even now consumed, large quantities of light oil. For the Navy oil was so eminently suitable as fuel that the demand in this direction would always raise its price above that due to its heat value. Furthermore, if there was ever a surplus after supplying the Navy, there remained the vast and ever-increasing demand by the Mercantile Marine, who would always be able to pay more for it than land consumers could do. It was therefore clear that coal must be our fuel where operations were carried on on a large scale. In the future, the oil consumers above mentioned would even be partly supplied from the by-products of our coal, instead of our burning any appreciable amount of oil for making electricity. It was therefore vital that our power-producing plant should be coal burning. The plant must be made suitable for the fuel, and not fuel found to suit a particular form of machinery.

The thermal efficiency of the plant for producing electricity was next considered. A good steam turbine and boiler plant

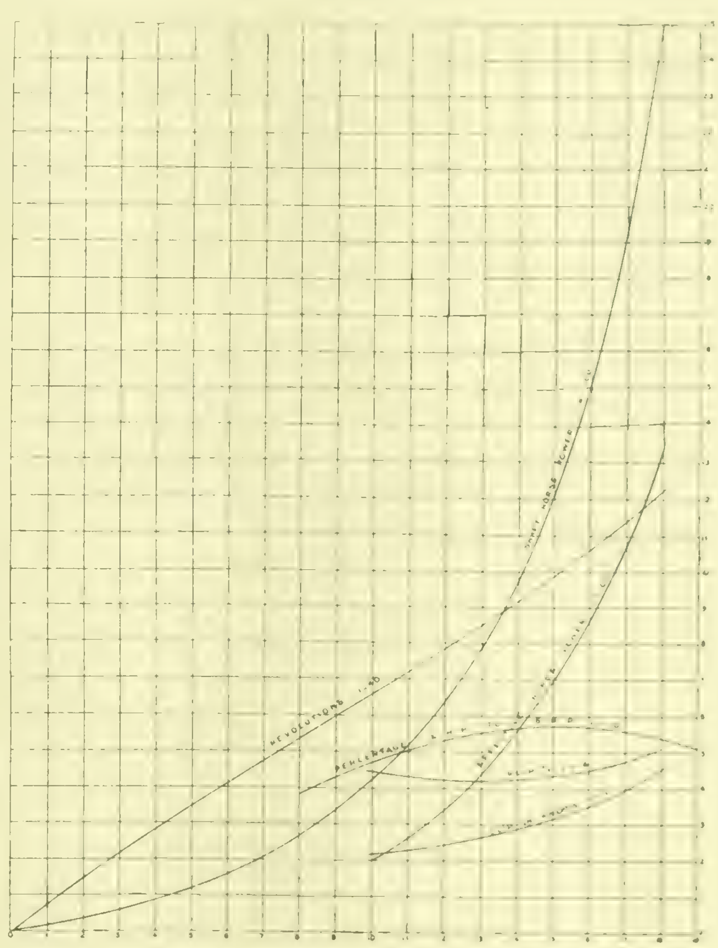


FIG. 3. PROGRESSIVE TRIAL RESULTS.

would to-day give back 15 per cent. of the energy of the fuel as electricity. As high an efficiency as 18½ per cent. had actually been obtained in practice. It was probable, however, that this was by no means the limit of economy, and that

developments in this class of machinery would result in an efficiency of 25 per cent. being obtained in the near future.

The next coal-burning machine considered was the gas engine. With it we had to consider not only the efficiency of the machine itself, but also that of the gas-producing plant. When the system was considered from this point of view its efficiency was probably between 20 and 22 per cent. With this process there should, of course, be worked by-product recovery. Although it appeared evident that in the future all coal must be gasified and its by-products recovered, it did not seem that present knowledge enables this to be done at sufficient profit for it to be generally adopted.

In the oil engine we had a machine which represents the highest efficiency yet realised. Moreover, test figures and those obtained in practice agreed very closely. The efficiency as already defined might be taken at between 28 and 30 per cent.

Dealing next with the question of stand-by losses, he mentioned that in the oil engine there was practically no loss under this heading. In the gas engine there was the producer loss and in the turbine the boiler loss. These would vary very much with the nature of the load, and where the plant was well designed and run, and the load factor was good, they might be reduced to a small quantity. Both the oil engine and the gas engine were, however, badly handicapped in relation to the steam turbine by their incapacity for dealing with overloads, which the station must always be in a position to meet.

With regard to the question of the labour involved in running and maintaining the plant, as matters stood to-day the turbine installation was undoubtedly the best, but it was hard to make a direct comparison, as the number of generating units with either gas or oil would be so great. It was, however, certain that the plant which was the simplest would always have the advantage, and where one was purely rotary and the other reciprocating there could be no question at all.

In the matter of capital cost the turbine system was again much the best, the simplicity, large units, and small space occupied contributing to this result. The size of the units on the turbine system compared with those on the other systems was perhaps the greatest determining factor in the case. The turbine was to-day adequate in fulfilling the demand, whereas the other two systems were not. Moreover, combined with its boilers and auxiliary plant, it was a simple means of generating power. Reliability of operation was, of course, vital, and here again the turbine system scored on account of its great simplicity, and because in working its parts were not subjected to either high or uncertain stresses.

In practice the turbine system had proved its capacity to meet the demand that was made on power-producing plant. All this showed that the course now followed by engineers in the selection of their plant was the right one, and that they really had no option in the matter. Looking at the question in the light of possible developments of the future, the author could not help thinking that as long as engines were used the rotary principle would be followed. For the moment the steam turbine system would be perfected so as to improve its efficiency and fuel consumption; later on, when the turbine could be made of the internal-combustion type, better economies still would be obtained.

THE MARCONI COMPANY'S WORKS AT CHELMSFORD.

ON Saturday, June 14th, a large party from the Institute of Marine Engineers visited the Chelmsford Works of the Marconi's Wireless Telegraph Company, Ltd. The works were originally established in 1898, but the rapid increase in business necessitated extensions, until, ultimately, a new site comprising about 10 acres was secured, on part of which were erected, in the early part of 1912, workshops to accommodate the 700 persons employed, and of dimensions which give an idea of the extent to which this new industry has been developed. The workshops occupy a space about 460ft. long by 150ft. wide. They are lofty and well lighted; a large number of wooden shafts in the roof form an efficient means of natural ventilation; and the heating is adequately effected by means of low-pressure hot water radiators. For protection against fire, water sprinklers are fitted throughout, and by an ingenious arrangement the doors connecting the various departments are automatically closed through the rise in temperature. The water supply is obtained from a 450ft. borehole and is conveyed to a water tower in which is a tank of 8,000 galls. capacity.

The first department visited was the mounting room, where coils of various sizes were seen in course of construction; also various field sets for military work. In another section were seen condensers in various stages of progress. These are in the form of a number of sheets of tinfoil, separated by waxed paper, the alternate sheets of tinfoil being connected so as to form two separate areas. Most of the fittings required are made in the works, and the machine shop, which contains a large number of machines of various descriptions, is roomy and well laid out with a view to facility in turning out the work. All the machines are electrically driven, the power being obtained from the works power station, which is equipped with De Laval turbines. The two steel masts for the aerials, 470ft. in height, are a conspicuous feature of the works. They are 4ft. 6in. diam. up to a height of 450ft., and are made of ½in. pressed steel in sections of 15ft., the distance between them being 700ft.

After looking through the carpenter's shop, mounting shop, and stores, some time was spent in the testing room, which is very completely equipped. The generating plant in this section includes two 30 kw. motor generators, a 50 h.p. motor, 2 kw. converter, giving 100 volts at 50 periods; a 3 kw. motor generator, giving 300 volts; a ½ kw. motor coupled to a Duddell high-periodicity generator, giving from 500 to 2,000 periods with a maximum speed of 9,000 revs. per minute; an alternating-current generator of 10,000 volts; and two direct-current machines, giving 3,000 volts. There are six alternating-current testing panels, for 1½ kw., 3 kw., 5 kw., 15 kw., 30 kw., and 60 kw. respectively; also six direct-current distribution boards for up to 3,000-volt circuits; and six high-tension 3-terminal boards for connecting to a volt meter reading up to 30,000 volts. A series of 36 tin plates hung on porcelain insulators in the roof of the building form an artificial aerial of variable capacity, resistance, and inductance; and four large oil baths containing galvanised-steel plates form another artificial aerial for measuring energy losses. An apparatus which will dissipate 20 kw. and will stand a pressure of 100,000 volts is installed to represent the energy lost by radiation in aerials. A Duddell oscillograph shows voltage and current-wave forms and the distorting effect of sparking; and a large number of other instruments are used for tests of various kinds, the majority of which are of a special nature and are designed by the Marconi Company's staff.

Demonstrations and explanations were given of the various instruments under working conditions, including a ½ kw. set as used on cargo vessels. Ships' installations are supplied up to the 15 kw. sets used on the large passenger liners. In one of the silence boxes in the instrument room, a number of the party had an opportunity of hearing messages transmitted from vessels at sea and from other stations.

The office buildings, which are constructed of brick, with stone facings, are well designed and well equipped. In one of the rooms the visitors were entertained to tea, and afterwards a hearty vote of thanks was accorded to the company and to the various assistants whose explanations had assisted in making the visit of such an interesting nature. Mr. John McLaren (Member of Council) proposed the vote of thanks, which was seconded by Mr. J. E. Elmslie (member), and responded to on behalf of the company by Mr. Eddington.

Maiden Voyage of the "Imperator."—The Hamburg-America liner "Imperator," the world's largest vessel, arrived at New York on Thursday morning, the 19th inst., on the completion of her maiden trip. In spite of various delays caused by fog and occasionally very stormy weather, the vessel attained an average speed of 21·13 knots.

Explosion in Liner's Hold.—An explosion occurred on the Royal Mail Steam Packet Company's liner "Avon" in Southampton Docks on the 17th inst. It was caused by spontaneous combustion in No. 3 hold, and blew up the hatches with a loud report. One of the hatches was hurled over the bridge, about 60ft. in the air, descending on the quayside. Flames and smoke belched out of the hatches, and it was at first feared serious consequences would follow. Fortunately, only three men were working in the hold at the time, and they escaped with slight injuries.

NOTES ON "GASEOUS HEATING."*

BY E. W. SMITH AND C. M. WALTER.

(*Continued from page 681.*)

Injectors.—When considering the question of air injection, due attention must be paid to the controlling factors, which may be enumerated as follows: (1) The amount of air injected will depend upon the mass rate of discharge of the gas through the jet, since, as will be seen later, we depend entirely on the momentum of the issuing stream of gas for imparting the requisite velocity to surrounding air. (2) The area of the surface of the gas stream in contact with the air should be as large as possible, consistent with clear injection—namely, that obtained without interference due to eddies brought about by unsatisfactory design of jets. (3) The entrance to the "vena contracta" should be designed so as to impede, in as small a degree as possible, the passage of the mixture through it, this being brought about by suitable shaping. (4) The diameter of the "vena contracta" should be such that sufficient velocity of the mixture is obtained to prevent back-firing.

The completeness of the mixture will be largely dependent on the expansion space beyond the "vena contracta." We will assume, for purposes of calculation, that the mixture passes into a zone at atmospheric pressure, although under actual works conditions we shall have a slight back pressure in the furnace which will tend to reduce the injection. Further, we shall assume that the air to be injected is also at atmospheric pressure, and at rest. Having then obtained the pressure of the gas which will produce, at the jet, a velocity which is consistent with the obtaining of the maximum mass rate of discharge, we can then obtain the theoretical volume of air which may be injected by equating the momentum of the gas to the momentum of the mixture. The variations from this figure in practice will be due partly to the imperfect intermingling of air and gas and partly to such effects as friction in the injector throat, and back-pressure in the burner tube. If we assume gas to flow adiabatically from a vessel where the pressure is p_o in pounds per square foot absolute to a place where its pressure is p_1 pounds per square foot absolute, then we find that the velocity of flow of the gas v is equal to

$$\sqrt{\frac{2g}{w_o}\frac{\gamma}{\gamma-1}\left(p_o^{1-\frac{1}{\gamma}} - p_1^{1-\frac{1}{\gamma}}\right)p_o^{\frac{1}{\gamma}}} \text{ ft./sec.} \quad . \quad . \quad . \quad (1)$$

Where w_o = weight of gas in pounds per cubic foot at pressure p_o

g = Acceleration due to gravity = 32·2 ft./sec. per sec.

γ = Ratio $\frac{\text{specific heat at constant pressure}}{\text{specific heat at constant volume}} = \frac{C_p}{C_v}$.

—*i.e.*, weight of gas which will flow/sec. through an orifice A. sq. ft. providing we have no friction

$$= A \times \sqrt{\frac{2g}{w_o}\frac{\gamma}{\gamma-1}\left(p_o^{1-\frac{1}{\gamma}} - p_1^{1-\frac{1}{\gamma}}\right)p_o^{\frac{1}{\gamma}}} \times w_1. \quad . \quad (2)$$

$$\text{and } w_1 = w_o\left(\frac{p_1}{p_o}\right)^{1/\gamma}$$

Thus w = quantity of gas flowing per second in pounds

$$= A\sqrt{\frac{2g\gamma}{\gamma-1}w_o p_o\left\{\left(\frac{p_1}{p_o}\right)^{\frac{2}{\gamma}} - \left(\frac{p_1}{p_o}\right)^{\frac{\gamma+1}{\gamma}}\right\}}$$

For the weight flow per second to be a maximum we have:—

$$\frac{p_1}{p_o} = \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$$\text{or } p_1 = p_o\left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}}$$

Substituting this value for p_1 in equation given above for v we get v_1 = limiting velocity for maximum massrate of

$$\text{discharge} = v_1 = \sqrt{\frac{2g}{w_o}\frac{\gamma}{\gamma+1}p_o} \text{ ft./sec.} \quad . \quad . \quad . \quad . \quad (4)$$

From 3 we have (for coal gas of density ·48 and

$$\frac{c_p}{c_v} = 1\cdot33)$$

$$\frac{p_1}{p_o} = \left(\frac{2}{2\cdot33}\right)^{\frac{1\cdot33}{\cdot33}}$$

$$\text{or } p_1 = \cdot540\, p_o$$

Substituting this value in equation 4 and taking p_1 = atmospheric pressure, we have

$p_o = \frac{1}{\cdot54}$ atmospheres

$g = 32\cdot2$

$\gamma = 1\cdot33$

$w_o = \frac{1}{v_o}$ where v_o = volume per pound at pressure p_o

also $p_o v_o = RT_o \therefore v_o = \frac{RT_o}{p_o}$ or $w_o = \frac{p_o}{RT_o}$ where R = J $(c_p - c_v)$ and T_o = absolute temperature

$$R = 110 \therefore w_o = \frac{1}{\cdot54} \times \frac{14\cdot7 \times 144}{110 \times 521} = \cdot0684$$

$\therefore$ Limiting velocity v_1 =

$$\sqrt{\frac{64\cdot4}{\cdot0684} \times \frac{1\cdot33}{2\cdot33} \times \frac{14\cdot7 \times 144}{\cdot540}} = 1450 \text{ ft./sec.} \quad (5)$$

Thus it will be seen that the limiting velocity of such a gas, for an adiabatic flow, if the condition of maximum mass rate of discharge holds, amounts to 1,450ft. per second, which velocity will be obtained with a gauge pressure of 25·5in. of mercury if the discharge is into atmosphere. This fact will incidentally explain why fittings, cocks, &c., if capable of withstanding this pressure of gas, are satisfactory for working at considerably higher pressures. It will be at once understood that from an injection point of view the most economical results will be obtained when the mass rate of discharge from the gas jet is a maximum.

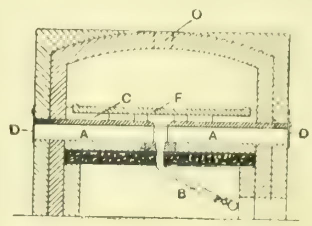


FIG. 5. SECTION THROUGH GAS-HEATED OVEN FURNACE.

Let us suppose that a stream of gas having velocity v_1 comes in contact with air at rest near an orifice through which the flow is guided. Then, assuming that there is no frictional loss through the orifice and that perfect intermingling of gas and air takes place if V = velocity with which the combined stream will pass through the orifice,

Then $V = \frac{v_1}{1+y}$ where $y = \frac{\text{weight of air passing per second.}}{\text{weight of gas passing per second.}}$

Then if K = sp. gr. of gas (air = 1).

Then the $\frac{\text{air}}{\text{gas}}$ ratio theoretically obtainable for a gas velocity

$$v_1 \text{ and mixture velocity } V = Ky = K\left(\frac{v_1}{V} - 1\right)$$

Taking $v_1 = 1450$, corresponding to a pressure of 25·5in. of mercury (gauge)

and V = 45ft. per second.

and K = ·48, then theoretical $\frac{\text{air}}{\text{gas}}$ ratio obtainable

$$= K\left(\frac{v_1}{V} - 1\right)$$

$$\cdot48\left(\frac{1450}{45} - 1\right)$$

$$= 14\cdot98$$

In practice, the figure obtained is very much lower, owing, in the first place, to the fact that the friction effect between the stream of gas and the surrounding air is not sufficient to obtain perfect intermingling; and, secondly, owing to the pressure in the throat of the injector not being atmospheric, as is supposed. Many methods have been tried for bringing about a better mixing of gas and air, among which are the multiple cone and the multiple jet. In the case of both these

* Abstract of paper read before the Institution of Gas Engineers, June, 1913.

systems, however, it was found that eddies were produced in the injector throat, and, owing to the back pressure thus brought about, the single jet was found to be more satisfactory. We find that, in the case of high-temperature furnaces, where gas is used at a pressure of about 12lbs. per square inch, a mixture velocity of about 45ft. per second gives excellent results.

TABLE I.

Type of Burner.	Gas Consumption. Cubic feet per hour.	Working Pressure.	Air/Gas Ratio of Mixture.	Velocity of Mixture at Burner Mouth. Feet per second.	Volumes of Secondary Air Required per 1 Vol. of Gas for Complete Combustion.	Remarks.
High-pressure Chamber burner fitted with ¾in. Keith injector	49·0	24in. in mercury	3·7	10·0	1·6	Aeration only sufficient to obtain stable flame at mouth of burner.
Ditto	Do.	Do.	8·0	19·3	—	Maximum air injection.
"S.-W." furnace burner	250	24in. mercury	10·1	112	—	Jet in position for maximum air injection.
Standard type cast-iron ring burner.	51·8	2in. water	3·3	4·2	1·1	Flame just stable. Maximum aeration.
Ditto	Do.	Do.	4·0	4·9	·4	"Lighting back" just taking place.

Table I. shows the results of a series of tests carried out with several standard types of low-pressure and high-pressure gas burners, with the object of determining—

(*a*) The $\frac{\text{air}}{\text{gas}}$ ratios obtained in the mixing-chambers.

(*b*) The velocities of the mixture at the burner mouth.

(*c*) The $\frac{\text{air}}{\text{gas}}$ ratio of the mixture, when "lighting-back" of the low-pressure burners occurred.

In each case, the $\frac{\text{air}}{\text{gas}}$ ratio was determined from an analysis of the mixture; and the theoretical $\frac{\text{air}}{\text{gas}}$ ratio for the complete combustion of the gas used was 5·3.

Application of Gas to Glass Manufacture.—A considerable amount of experimental work has been recently carried out in Birmingham in connection with the application of town gas for glass-ware manufacture, and as a result several large manufacturers have adopted gas for heating their lehrs, glory holes, and sand kilns. Several melting furnaces and tanks are also about to be installed. Experiments have also been recently carried out in connection with the melting of glass itself. Bottle glass has been melted by means of high-pressure gas in tank furnaces; the metal having been planed from the raw cullet and batch with every satisfaction. Flint glass has also been melted in pots. To obtain economical results in this application, however, it is found that regenerative settings must be used. Other applications of gaseous heating in connection with glass manufacture include glass bending, furnaces and sand drying kilns; both these processes having been carried out on a large scale and proving to be commercially satisfactory.

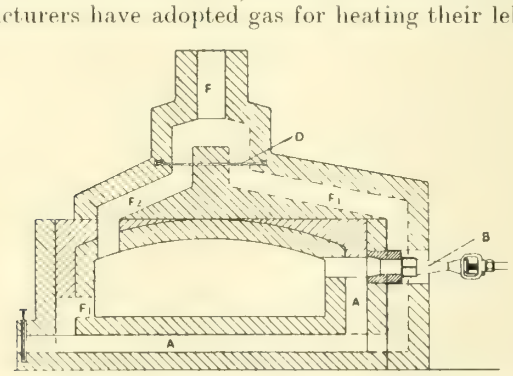


FIG. 6.—SECTION THROUGH REGENERATIVE REVERBERATORY FURNACE.

Tempering, Hardening, and Annealing Furnaces.—In hardening, annealing, and tempering furnaces, we have to consider processes where a large amount of heat at a moderately low potential is required. It must be remembered that this soaking process necessarily requires a big body of heat. With regard to the annealing of brass and steel stampings, it was at one time quite a prevalent idea among manufacturers that no such work could be carried out unless in a closed muffle; it being maintained that were such work carried out in furnaces of the oven type the oxidation of the work would be excessive. Such might be the case if furnaces fitted with air-blast burners were under consideration. With the development of the oven furnace fitted with atmospheric burners, however, all such ideas have long become exploded; and it is now an established fact that for best results to be obtained the oven furnace must be used for this purpose.

In the oven furnace with the bottom slab heated by the large flames from atmospheric burners, we obtain just the effect that is required by these soaking processes; the poorly aërated flame which partly envelopes the work being an absolute necessity for the best results to be obtained. Further, if suitable arrangements are made to enable the amount of secondary air entering the furnace to be controlled, then the work can be carried out with a minimum of oxidation; for it will be understood that if such a furnace be run with the damper so adjusted that a slight back pressure is obtained, and if the amount of secondary air entering the furnace is only just sufficient for complete combustion of the gas, then the work is continuously sealed from the atmosphere by the products of combustion with which it is surrounded.

Fig. 5 represents a furnace of this type suitable for annealing purposes, and also for the tempering and hardening of steel, case-hardening, and all such processes which require this soaking effect at any temperatures up to 1,200° C.—this temperature being maintained quite easily with a gas pressure of 3½in. to 4in. water gauge. It will be seen that the burners B are arranged in a line entering the bottom of the furnace in the centre. The whole of the secondary air being admitted through the flues A A and controlled by the dampers D D, combustion takes place in the chamber C, beneath the floor of the furnace F; the waste gases passing into the oven itself through nostrils at the sides and finally entering the flue outlet O. It will be observed that the secondary air flues A are so arranged that a considerable preheating effect is obtained; and although such a system of preheating may not be considered either as regenerative or recuperative by reason of the heat supplied to the secondary air not being abstracted directly from the waste gases, the net results obtained with such a system are, nevertheless, much the same, as a certain amount of heat is being continually transferred by means of the secondary air from the oven slab to the sides and roof, which results in very uniform heating being maintained throughout the whole of the working space.

As regards the working pressures suitable for this class of work, the results of a considerable number of experiments show that, disregarding for the moment the time taken for the preliminary heating up of the furnace, no advantage is obtained when working with pressures higher than 4in. of water gauge. With this pressure, temperatures up to 1,200° C. can be maintained. The best results are obtained when the aëration is only just sufficient to allow the required temperature being maintained—that is to say, the volume of the flame should be a maximum for the temperature required. Furnaces of this type are particularly suitable for the annealing of brass and steel stampings, where temperatures of from 800° to 950° C. have to be maintained; also for the case-hardening of steel, where temperatures up to 1,100° C. are

required. As regards case-hardening, it will be found that little or no carbon absorption will take place at temperatures below 900° C.; the best results being obtained by soaking at as low a temperature as possible for a long period, rather than working at a higher temperature for a shorter period.

For normal carbon steels, it is usual to case at a temperature of about 1,050° C., quench when the required depth of casing has been obtained, re-heat to a temperature of about 950° C., and quenching again finally in oil or water, according to the particular degree of hardness required. For both the processes of case-hardening and re-heating this type of furnace is admirably suited.

Fig. 6 represents a section through a regenerative, reverberatory furnace, suitable for use with either low-pressure or high-pressure gas; the working pressure depending on the temperature required. It will be seen that the burners B are placed in a line, entering the side of the furnace, and so arranged that the flame impinges on the arch; the waste gases passing over the work, and hence into the flue outlet F_1, situated at the bottom on the opposite side, whence they are conducted beneath the bed of the furnace into the main flue F, giving up their heat to the secondary air, which passes through the flues A arranged alternately with the waste-gas flues beneath the furnace bed. It will be further observed that an auxiliary flue outlet F_2 is provided. This is necessary to prevent any short-circuiting taking place when the furnace door is opened; the dampers being so arranged that, when the furnace door is opened, F_1 is closed and F_2 opened simultaneously. Furnaces of this type are very suitable for any class of annealing operation where the work itself does not offer an obstruction to the flames, such as plate annealing and the annealing of stampings. Temperatures up to 1,500° C. may be obtained with a working pressure of about 100in. water. A similar design of furnace may also be adopted for forging, welding, and the hardening of high-speed steels.

(*To be continued.*)

PETROL-ELECTRIC MOTOR-VEHICLES.*

BY J. B. G. DAMOISEAU.

(*Concluded from page 673.*)

ADVANTAGES AND DISADVANTAGES OF THE VARIOUS PETROL-ELECTRIC SYSTEMS.

Thomas System.—The position of the engine depends on that of the axles to be driven. For cars with a long wheelbase, the mechanical transmission must be considerably extended if the engine drives the axles of the two bogies. To reduce the length of the transmission the engine need only drive one bogie. The engine, owing to the mechanical transmission, is subject to shocks when the wheels pass over joints in the rails, points, &c. Spring devices can be inserted between the axles and the engine to minimise the effect of these shocks, but the mechanism is thereby complicated still more. The engine must be designed so that it can rotate in both directions, *i.e.*, it must be stopped before the direction of motion of the car is changed.

The speed of the engine is independent of the speed of the car; the engine may thus run at a speed which allows it to give its maximum power. The direct drive (the engine driving direct on to the axles) corresponds only to one value of the tractive effort at the rims of the wheels, and consequently to only one value of the gradient of the track. For every other gradient the speed of the car is different from that of the engine, and the electro-mechanical transmission comes in, so that the total output must not be greater than that of the electric transmission. The size of the engine is determined by the maximum power to be supplied to the car (the battery only serving to start the engine). The maximum power of the engine may be utilised, no matter what may be the gradients of the track, having regard, of course, to the heating of the dynamos.

The capacity of each of the two dynamos is equal to two-fifths of that of the engine, or for the two dynamos together a total of four-fifths. The weight and cost of these two dynamos are less than those of the generators and motors in the case of electrical transmission, but account must be taken of the weight and price of the mechanical transmission, which is relatively very complex (viz., epicyclic gear, concentric shafts, cardan shaft, &c.). Other conditions being the same, the total cost of this mixed transmission is at least equal to that of the electric transmission, whilst the weight is practically the same.

Pieper System.—The above remarks on the Thomas system, as regards the position of the engine, the importance of mechanical transmission, the shocks resulting when crossing points, &c., and the rotation of the engine in either direction, apply equally to the Pieper system. The engine driving always direct on to the axles, its speed depends on that of the car. The engine cannot revolve, therefore, steadily at the speed which would give it its maximum output. The power of the engine is determined by the total work to be supplied to the car for a journey to and fro on a certain line, together with the loss of energy in the dynamo and battery. As the speed of the engine and the admission are variable, the result is that this engine, other things being equal, has practically the same dimensions as an engine for electric transmission. The capacity of the dynamo is less than that of the generator for electric transmission, but its speed is invariably determined by that of the car. The capacity of the dynamo and the capacity of the battery become more important in proportion as the track is more hilly and the stations are closer together. The regeneration on gradients and during braking is particularly important on lines having many gradients, or in the case of relatively short distances between the stations.

This system, like that of the accumulator-driven car, presents disadvantages in so far as a battery is required. Other things being the same, this petrol-electric equipment, which has a battery in addition to mechanical transmission and electromagnetic clutches, costs practically the same, and weighs no more than the petrol-electric equipment with plain electric transmission.

Cars with Electric Transmission.—The position of the engine is independent of that of the axles to be driven. Simple wires establish the electric connection between the generators and the motors driving the axles; this electric connection, being flexible, cannot transmit to the generating plant the vibrations caused by the track. The engine always rotates in the same direction, the change in direction of the car being brought about by a change in the direction of rotation of the electric motors without stopping the engine. The speed of the engine is independent of that of the car. The engine can rotate at a speed which allows it to give the maximum power at the maximum thermal efficiency. The power of the engine is determined by the maximum power to be supplied to the car, taking the output of the dynamos into account. This maximum power of the engine can be utilised no matter what the inclination of the track may be, provided the limiting temperature of the dynamos is not exceeded. The total capacity of the generator and motors is about double that of the engine.

From this brief comparison it follows that the simplicity of the electric transmission and its flexibility justify its almost exclusive adoption to cars or with electric transmission. It is in fact of no little importance, from the point of view of the economical operation of a railway, to achieve two results, which appear to be diametrically opposed to each other and which illustrate what may be called the elasticity of the motor-vehicle: (1) The speed of the car can be raised gradually up to its maximum and maintained at any intermediate speed, so as, for instance, to keep a particular distance (indicated by the signals or schedule) between the motor-vehicle and the preceding train, no matter what the speed of the latter may be. (2) The speed of the motor-vehicle can be maintained as constant as possible on various gradients.

The very extensive range of speed is obtained very easily by varying the excitation which has the advantage of affecting an item which is less than 4 per cent. of the maximum capacity of the generator. By reason of the small amount of power in the control circuit the control apparatus, whilst being of small dimensions, can have a great number of notches for varying gradually the pressure generated at the terminals of the dynamo.

LIQUID FUELS.

The liquid fuels used for motor-vehicles are: gasolene or petrol (density, 0·680—0·720) and benzol (density, 0·885). In countries where there are no supplies of petrol, the present practice is to use benzol, which is a natural product distilled from coal-tar. These two fuels have practically the same

* Paper presented at the joint meeting of the Institution of Electrical Engineers and the Société Internationale des Electriciens, Paris, May 21st—24th, 1913.

calorific value, produce almost the same power from the engine, and can be used alternatively without any modification of the plant. When using benzol it is necessary to start with petrol because benzol requires a certain amount of pre-heating.

In France the price of benzol is about 0·25 franc per litre, whilst petrol, owing to the duty, costs 0·35 franc. The cost of fuel could be very much reduced by using heavy oils derived from the distillation of petroleum or tar, the prices of which are at present relatively low. However, as these heavy oils cannot be reduced to a gaseous condition by evaporation like the fuels just considered, they must be injected into the engine in a liquid state. This necessity has led to the adoption of the internal combustion engine with constant pressure. The cycle of this engine is economical, since the compression (35 kg. to 40 kg.) is much greater than that (4 kg. to 5 kg.) used in engines with constant volume, which operate on the Beau de Rochas cycle. This high compression requires a strongly constructed machine, the heavy masses of which do not allow, on account of their inertia, the same rotatory speed to be obtained as in the case of petrol engines. On that account the price of the generating set is higher, both as regards the engine and the generator. Of the existing petrol-electric cars, only two cars at present undergoing trials on the Swedish State Railways are equipped with petroleum engines. The results will be watched with interest.

INITIAL COST, AND COST OF OPERATION.

The cost of petrol-electric cars depends on their power, size, the furnishing of the interior, and on many other secondary factors, such as the number of cars of the same type constructed at the same time, the country in which the cars are constructed, &c. There is no common basis, therefore, on which to estimate the cost except that of size. The price of a petrol-electric car varies from 40,000 to 150,000 francs. A 90 h.p. car weighing 20 tons and having seating accommodation for 40 passengers costs about 50,000 francs. The 120 h.p. car of the type used on the Prussian State Railways, which weighs 50 tons and provides accommodation for 100 passengers, costs about 90,000 francs when fitted up for third and fourth-class traffic. The motor-vehicle of the General Electric Company, weighing from 40 to 50 tons, with accommodation for from 60 to 100 passengers, costs from 100,000 to 150,000 francs, according to the furnishing of the interior. The cost varies in consequence from 1·80 to 3 francs per kilogram.

Fuel Consumption and Cost.—The consumption of fuel by a motor-vehicle depends on the power required for propulsion, and the efficiency of the transmission. The power required for propulsion is essentially a variable quantity depending on the profile of the line, the distance apart of the stations, the length of stop at each station, the time taken to complete the journey, the weight of the motor-vehicle, and the weight of the trailers. The consumption of fuel therefore depends on the above factors, and varies in consequence for the same car according to the traffic of the line on which it is operated. It follows, therefore, that when making a comparison between different types of petrol-electric cars, it is not possible to introduce figures for the consumption of fuel per ton-kilometre, as the cars would not be in service on the same line.

Moreover, the consumption expressed per ton-kilometre is unable to furnish any reliable indication, seeing that on the one hand the track-resistance per ton of the train weight is a function of the weight, speed (owing to the effect of wind resistance), and composition of the train, and on the other hand the electrical output required increases with the nominal power, *i.e.*, with the weight and speed of the train. For these two reasons, of which the former is the more important, the energy consumption per ton-kilometre is a function of the weight and speed of the train.

The consumption of fuel per ton-kilometre varies in practice between 15 and 30 grammes, according to the profile of the line and the condition of the track. It may even reach 40 grammes per ton-kilometre if the route is very hilly. The cost of fuel therefore varies per ton-kilometre in the case of petrol from 0·0075 to 0·015 franc, and in the case of benzol from 0·0042 to 0·0084 franc.

Cost of Lubrication.—The cost of lubrication for the car itself, apart from the petrol-electric equipment, varies between 0·0005 and 0·0010 franc per ton-kilometre.

Cost of Maintenance and Repairs.—As the petrol-electric system has, comparatively speaking, been only recently introduced and has been applied in only a few instances, sufficient time has not elapsed to enable exact data to be obtained with regard to maintenance and repairs. Naturally these expenses increase with the number of years a motor-vehicle has been in service. It is likewise necessary to know the rate of depreciation for such cars, or at least of the petrol-electric equipment, in order to be able to fix the corresponding allowance per annum for this item. The only line on which this system of traction has been in use for some time is the Hungarian Arad Osanad system. But owing to the continual improvements and changes effected in motor-vehicles, it is difficult to fix exactly the various expenses for the repair and maintenance of the cars. On the other hand, the petrol-electric system is a development of such importance that the maintenance of the equipment would be carried out on a large scale and consequently in a comparatively economical manner. Railway systems with only a limited number of such cars, however, would be in a less favourable position.

By examining the cost of repairs and maintenance of the cars at present in service in Europe and America, we may gather that this expense per ton-kilometre varies, according to the age of the car, between 0·0015 and 0·0040 franc.

TOTAL COST OF RUNNING PETROL-ELECTRIC VEHICLES.

Assuming that the fuel used is benzol, as is the case in France, the cost of running cars on the petrol-electric system is as follows, the figures being given per ton-kilometre:—

	Franc.		Franc.
Fuel (benzol)	0·0042	to	0·0084
Lubrication	0·0005	,,	0·0010
Repairs and maintenance	0·0015	,,	0·0040
Total running expenses	0·0062	to	0·0134

The driver's wages may be taken as 0·0040 franc per ton-kilometre.

As regards "amortisation," although the time that such cars have been in use is too short to allow the "wear and tear" and depreciation to be determined from experience, it appears that if we take 10 per cent. per annum of the value of the total equipment, including the car itself, this estimate is if anything rather too high. As an annual mileage of 50,000 km. may be expected per car, this means that "amortisation" represents about 0·005 franc per ton-kilometre.

If interest on the capital invested is taken as 5 per cent., this represents 0·0025 franc per ton-kilometre. Thus the total cost of running, if wages, "amortisation," and interest are taken into account, is 0·0177 to 00·249 franc per ton-kilometre.

ANNUAL MILEAGE AND ACTUAL "SERVICE EFFICIENCY."

In order to show that these cars can be relied upon for the operation of a railway system it may be pointed out that petrol-electric cars on the Hungarian Arad Osanad Railway system have run more than 50,000 km. without being taken out of service for repairs. On this railway system the 40 h.p. motor-vehicles average 45,000 km. per annum, and the 70 h.p. trains about 55,000 km.

It has not been possible to ascertain the "service efficiency" of these motor-cars—by "service efficiency" is meant the ratio between the average annual mileage actually realised by each car and the theoretical annual mileage which each car might have realised without interfering with the service. However, the efficiency for the petrol-electric vehicles is higher than that of steam motor-cars, the figure for the latter taken over all the systems where such cars are used varying between 29 and 65 per cent.

ERECTION OF FUEL DEPÔTS.

The depôts for the fuel must be placed so as to exclude all danger of fire. For this purpose the fuel may be kept in a covered tank under water (as in the case of the Arad Osanad Railway system). The depôts may also make use of the arrangement adopted by the Compagnie Génerale des Omnibus de Paris for their depôts for hydrocarbon oils, viz., always to cover such oils with an atmosphere of inert gas, such as nitrogen or carbonic acid, and to prevent the hydrocarbon oils from coming in contact with the air, under all circumstances.

LINES SUITABLE FOR PETROL-ELECTRIC CARS.

What are the characteristics of the lines which can be worked by petrol-electric cars? They must have a relatively small but constant traffic: small traffic, because the working

of a line by petrol-electric cars can only be economical with light trains; and relatively constant traffic, because the limited power of these cars does not allow heavy trains to be run. The petrol-electric cars which have been constructed up to the present time are only built to haul one or two trailers.

The introduction of motor-cars on a railway system necessarily leads to the disappearance of mixed trains (passenger and goods trains combined), since such trains cannot be economically dealt with by that system of traction. It is therefore necessary for the goods trains to be hauled by steam locomotives. On days of dense traffic, trains of heavier tonnage than usual can be drawn by the steam locomotives which are usually employed to haul the goods trains, such locomotives replacing the motor-vehicles or being inserted between them. It is evident that the use of motor-vehicles is only advisable when such changes in traffic are not too frequent.

Since the operation of a system by petrol-electric cars allows a greater frequency of trains than in the case of steam engines, such an increase in traffic might result that the introduction of electric traction would be justified, as electric traction brings about still greater economy and a still greater frequency of trains. This result of course is exceptional.

DEVELOPMENT OF STEAM MOTOR-CARS, ACCUMULATOR CARS, AND MOTOR-VEHICLES WITH PETROL AND MECHANICAL TRANSMISSION.

To show the importance of the adoption of petrol-electric cars, it is sufficient to compare these with the independent motor cars that preceded this system. Steam motor-cars were the first independent motor vehicles to be used on railways. Their introduction dates back almost to the introduction of railways themselves, the first use of them having been made in 1819 between London and Norwich. This type of car has the advantage of age, i.e., of a lengthy trial, and offers railway companies the advantage of dealing with the same conditions as in the case of steam locomotives, i.e., to be able to employ for the running and maintenance of the cars the same staff as for steam locomotives. Steam motor cars have really only begun to be widely adopted since 1895, and are relatively few. In 1910 the total number in service in Europe was estimated at about 400, of which more than half were in the United Kingdom and the Colonies. At the present time the number in use is practically the same, most of the companies who are using them not having given repeat orders.

The accumulator cars which were introduced to remedy the disadvantages of steam motor-cars are even less numerous than the latter. Apart from the accumulator cars—relatively few in number—owned by the Prussian State Railways, there are only three on trial on the Bavarian, Saxon, and Belgian State Railways. This type of independent motor vehicle has been altogether abandoned since the introduction of the petrol electric car.

The internal combustion engine car with entirely mechanical transmission preceded the petrol-electric car. In Europe, with the exception of inspection cars, which are of low power, seven petrol cars with mechanical transmission are at

TABLE I.

Constructed by—	No.	Horse-power.	Weight in tons.	No. of passengers carried.	Railway.	Remark.
British Westinghouse Company	1	80	35	52	North-Eastern Railway (England)	On trial
Société de Dion-Bouton	36	30	13	12	Arad Osanad (Hungary)	
		70	16·3	39		
Société Westinghouse du Havre	2	60	13	48	,, ,,	
		80	17	42		
,, ,, ,, ...	1	55	18	36	Ostdeutsche Elektricitat. Gesellschaft (Germany)	
,, ,, ,, ...	1	90	—	—	Hungarian State	
,, ,, ,, ...	18	90	16	Luggage	Oostertoomstram (Holland)	Five under construction
,, ,, ,, ...	1	90	19·5	38	Dinard, Saint Brieuc (Ile et Vilaine)	
,, ,, ,, ...	2	60	23	55	Mines de Carvin (Pas de Calais)	
,, ,, ,, ...	1	90	25	35	Karlstad Munkfors (Sweden)	
,, ,, ,, ...	1	90	24	40	Great Central Railway (England)	
,, ,, ,, ...	2	90	21	45	Vicinaux de Luxembourg	Under construction
,, ,, ,, ...	7	90	30	60	Missouri Oklahama Gulf Rly.,U.S.A.	,, ,,
,, ,, ,, ...	2	90	22	35	Ferrocarriles Vascongados (Spain)	,, ,,
,, ,, ,, ...	5	90	22	35	Grande Banlieue (Paris)	,, ,,
,, ,, ,, ...	1	90	24	32	Caen à la Mer (Calvados)	,, ,,
Bergmann Elektricitäts Aktien-Gesellschaft	3	100	47	100	Prussian State	,, ,,
,, ,, ,,	1	50	47	100	,, ,,	,, ,,
,, ,, ,,	6	170	47	100	,, ,,	
,, ,, ,,	1	100	47	100	Resaner Bahn (Moscow)	
,, ,, ,,	1	100	47	100	,, ,, ,,	Under construction
,, ,, ,,	3	30	47	100	Tramways	
Allgemeine Elektricitäts Gesellschaft	1	90	47	100	Prussian State	
,, ,, ,, ...	6	100	56	95	,, ,,	
,, ,, ,, ...	1	120	56	95	,, ,,	
,, ,, ,, ...	1	100	56	95	Oldenburg State	
,, ,, ,, ...	1	2 × 120	56	95	Khedive (Egypt)	Double car under construction
,, ,, ,, ...	1	55	56	95	West Germany (Konigsberg)	
General Electric Company	2	55	40 to 50	60 to 100	,, ,, ,,	
British Thomson-Houston Company	1	55	14	41	Great Western Railway (England)	
Almänna Svenska Elektriska Aktie-bolaget ..	2	75	26	39	Swedish State	Diesel motor
Pieper System	4	90	26	39	Vicinaux Belges Mons—Frameries	
,, ,, ...	4	90	26	39	Vicinaux Belges Rhode—Waterloo	
,, ,, ...	3	90	21·7	49	Chemin de fer de Grande Banlieue Poissy—Saint Germain	
Thomas System	1	120	21·5	42	South African Railway	

SUMMARY.

	Motor vehicles.
British Westinghouse Company	1
Société de Dion Bouton	36
Société Westinghouse du Havre	44
Bergmann Elektricitäts Aktien-Gesellschaft	15
Allgemeine Elektricitäts Gesellschaft	11
British Thomson-Houston Company	1
Almänna Svenska Elektriska Aktie-bolaget	2
Pieper System	11
Thomas System	1
General Electric Company	2
Total	124

present in service on four foreign railway systems. In America, owing to the fact that the tracks are almost level, or at least with only slight gradients, these cars have been more widely adopted.

Petrol-electric cars, the last-comers, seeing that they were first introduced as recently as 1905, have been adopted on a considerable number of railway systems. The accompanying table shows the number, weight, and size of the petrol-electric cars in use on the various railway systems. If the more important French railway companies have so far not adopted the petrol-electric system of traction it must be attributed to the fact that the branch lines on which such cars might be utilised are worked with old rolling stock, in good condition but no longer of use on the main lines.

On branch lines, where the journeys are relatively short, comfort is only a secondary consideration; old rolling stock is used to good advantage, and does not require any special knowledge on the part of the operating staff, as regards driving, maintenance, and repairs. The use of such vehicles, moreover, has the further advantage on days of dense traffic (such as market-days) that it is possible to meet the requirements of this traffic by means of mixed trains, as the locomotives are powerful enough for that purpose. On the other hand, the consumption of coal by locomotives for light trains being only about 9 kg. or 10 kg. per train-kilometre, the cost of the fuel is about 0·18 to 0·20 franc per train-kilometre, or a little less than in the case of the petrol-electric vehicle, should the weight of the latter be more than 40 tons.

However, if the important French railway companies for the above reasons have not adopted this type of motor-vehicle, the trials carried out by three important English railway companies with petrol-electric cars are worthy of notice as they show that these companies are interested in this kind of traction and are applying it to their lines.

CONCLUSIONS.

The four types of independent motor-vehicles are at present: steam, accumulator, petrol with mechanical transmission, and petrol-electric. Accumulator cars have, however, been abandoned, and as the petrol engine with mechanical transmission has not been found sufficiently flexible, there remain therefore at present only the steam motor-car and the petrol-electric vehicle. The characteristics previously enumerated for petrol-electric cars emphasize the short-comings of the steam motor-car, and the conclusion may therefore be drawn that if the use of independent motor-vehicles continues to develop—and there is no reason why it should not—then petrol-electric motor-vehicles will preponderate.

STUDIES IN THE COLD FLOW OF STEEL.*

BY PERCY LONGMUIR.

A PAPER dealing with some aspects of wire drawing was presented at the last meeting of this Institute, and the present paper represents further work in the same direction. Owing to the complexity of the changes induced by cold flow, results can only be presented after repeated confirmation. Possibly no other field of metallurgical research stands in such need of repeated confirmation as that of studies in cold flow. A good illustration of this lies in the generally accepted view that the density of metals is increased by cold work. Thus Brunton† has shown that: "It is possible to increase the specific gravity of steel to 7·998 from 7·768 by cold work, and when it reaches this point and is again subjected to a crushing action by pulling through a die, it actually gets lighter, showing that it is impossible by this means to make it more dense."

In 1904 Kahlbaum showed a loss of density in platinum due to drawing, and one set of results are as follows:—

	Specific Gravity.
Rolled and forged rod, 3 mm. diam.	21·4314
Wire, cold-drawn to 1 mm.	21·4136
„ annealed three minutes at a white heat	21·4314
„ cold-drawn to 0·7 mm.	21·4181
„ annealed three minutes at a white heat	21·4314
„ cold-drawn to 0·4 mm.	21·4142
„ annealed three minutes at a white heat	21·4308

* Abstract of paper presented at the annual meeting of the Iron and Steel Institute, May, 1913.

† "Journal of the Iron and Steel Institute," 1906, No. II.

Goerens‡ quotes various authorities, and shows that "more recent experimental evidence supports the view that the density of cold-worked metals is increased by annealing, that is, by the change into the soft condition."

With steels, the initial difficulty lies in obtaining repeated confirmation, and, although this may be due to varying errors in determination, there is still a range of variation due to sources outside those of experimental error in method.

The work done in this section has not proved conclusive, and no definite rule has been found. Various classes of steel of varying carbon content have been tested at different stages of drawing, from 5-gauge rod to 25-gauge wire, and in the absence of overdrawing there is an apparent tendency to decrease in specific gravity as the wire is diminished in size by drawing. Further, the increase in maximum stress values due to cold work is not necessarily associated with a rise in specific gravity. However, this aspect of the subject requires far more investigation than has hitherto been made before definite statements can be made.

I.—A series of steels have been drawn by successive reductions of 0·001in. from rod to fine gauge wire. The original rods were annealed, but no heat treatments were applied during drawing. The analyses of three of the steels are:—

	Steel No. 1.	Steel No. 2.	Steel No. 3.
	Per cent.	Per cent.	Per cent.
Carbon	0·10	0·48	0·89
Manganese	0·89	0·87	0·78
Silicon	0·06	0·058	0·07
Sulphur	0·103	0·039	0·035
Phosphorus	0·307	0·050	0·046

After annealing in the rod these steels were drawn down by successive reductions of 0·001in. until they would not admit of further cold flow. Details of Nos. 1 and 2 have been previously published by the author,§ but, taking the three steels together, the effect of cold work in successive small increments may be summarised as follows:—

Tensile Tests.

No.	Condition.	Total reduction in drawing per cent.	Maximum stress, tons per square inch.	Elongation per cent. on 2 inches.	Reduction of area per cent.
1	Annealed rod, 0·201in.	—	35·98	31·15	67·82
	Wire, 0·072in.	98·7	75·63	2·0	41·46
	Wire, 0·024in.	—	112·0	2·4	—
2	Annealed rod, 0·214in.	—	43·48	16·9	54·87
	Wire, 0·072in.	92·3	90·0	2·0	19·57
	Wire, 0·056in.	—	100·0	1·5	4·56
3	Annealed rod, 0·212in.	—	50·87	16·55	45·89
	Wire, 0·072in.	88·1	104·0	1·5	3·24

As the 0·89 per cent. carbon steel (No. 3) could not be drawn beyond 0·072 or 15-gauge without heat treatment, the corresponding values for Nos. 1 and 2 are included. This comparison table is of considerable interest. For example, a steel containing 0·1 per cent. sulphur and 0·3 per cent. phosphorus by cold flow alone admits of an initial maximum stress value of about 36 tons per square inch being raised to the high value of 112 tons. This class of steel is largely used in the form of drawn bars or wire for use in automatic lathes for the rapid production of machine details. Although so largely used, and in spite of the admirable flow illustrated here, the steel is not safe as regards resistance to suddenly applied loads.

Steel No. 2, which is normal as regards analysis and contains 0·48 per cent. carbon, has its stress value raised by cold work from about 43·5 to 100 tons per square inch.

Steel No. 3 shows a nearly corresponding increase, and it is an interesting fact to note that the final effect of cold work, as judged by tensile tests, does not materially differ in the case of three steels very dissimilar in composition. Intermediate effects are shown in the Curves Figs. 1, 2, and 3. Taking Curve Fig. 1 first, the maximum stress values of the three steels are shown at each stage of cold drawing. The

‡ Ibid., 1911, No. III.

§ "Journal of the Iron and Steel Institute," 1912, No. II.

chief interest here lies in the fact that no real breaking-down point is indicated in any of the steels. Curve Fig. 2, whilst more erratic than Fig. 1, still shows that, as far as reduction of area after fracture by tension is concerned, there is still no sudden breaking-down point. With maximum stress values the increments fall on a more or less gradually inclined line, and a very similar remark is applicable to the comparatively steady decreasing values in reduction of area after the fracture.

These features are not shown in Curve Fig. 3, for the elongation after fracture rapidly falls, and then becomes almost steady, irrespective of further cold work. It will be noted that with each steel after passing a certain point a nearly straight line follows, and, further, the three steels do not give widely dissimilar values.

It should be noted that the foregoing do not represent commercial conditions of drawing; the reductions per pass are slight, and the results obtained represent the effect of flow in successively small stages.

II.—Steel No. 1 shows that the presence of appreciable percentages of sulphur and phosphorus does not retard flow. The effect of various elements has been examined, but for the present it will suffice to give an illustration from a silicon steel drawn under commercial conditions. Silicon, when present in a steel in ranges varying from traces to 2·5 per cent., does not materially affect flow, providing annealing and cleaning conditions are suitably modified. The following steel contains, in addition to silicon, an appreciable amount of aluminium:—

Steel No. 4.

	Per Cent.
Carbon	0·25
Manganese	0·35
Silicon	2·50
Sulphur	0·025
Phosphorus	0·020
Aluminium	0·75

The flow effects, as judged by tensile tests at each stage of commercial drawing, are shown in the following table.

Steel No. 4.

Gauge. Before.	Gauge. After.	Decimal taken off inch.	Tensile Test. Maximum stress, tons per sq. inch.	Tensile Test. Elongation per cent. on 2 inches.	Tensile Test. Reduction of area per cent.	State of Wire or Process.
4			50·26	18·75	56·74	Rod. As annealed. Cleaned and limed.
4	6	0·04	68·82	6·00	44·25	After first hole.
6	—	—	40·00	27·50	60·07	As annealed.
6	7	0·016	48·14	9·00	60·00	After second hole.
7	9	0·032	59·36	5·50	50·69	After third hole.
9	—	—	40·00	25·00	54·43	As annealed.
9	11	0·028	59·00	6·00	29·41	After fourth hole.
11	13	0·024	61·00	3·00	22·32	After fifth hole.
13	—	—	41·00	21·20	76·66	As annealed.
13	15	0·020	56·00	5·00	67·60	After sixth hole.
15	17	0·016	65·00	4·00	61·20	After seventh hole.
17	—	—	44·30	23·50	80·00	As annealed.
17	18	0·006	53·00	2·25	53·33	After eighth hole.
18	20	0·012	74·50	2·70	58·83	After ninth hole.

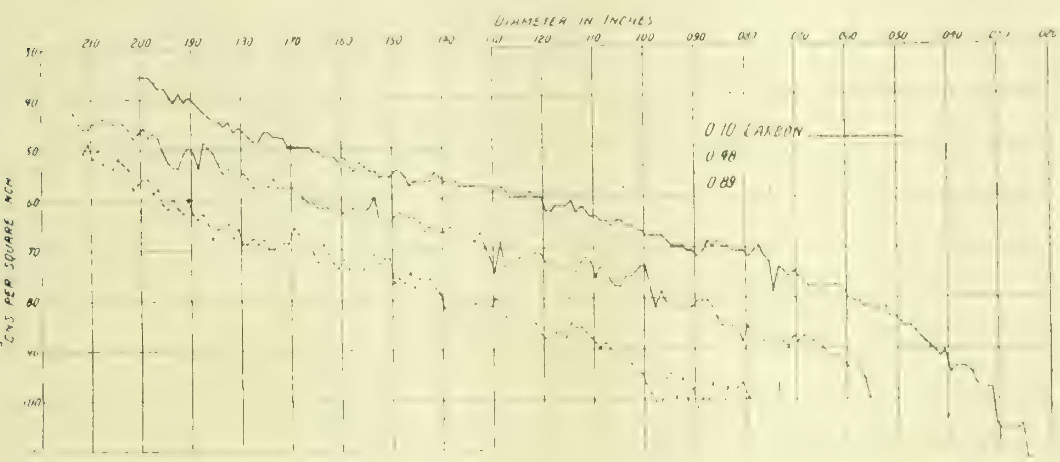


FIG. 1

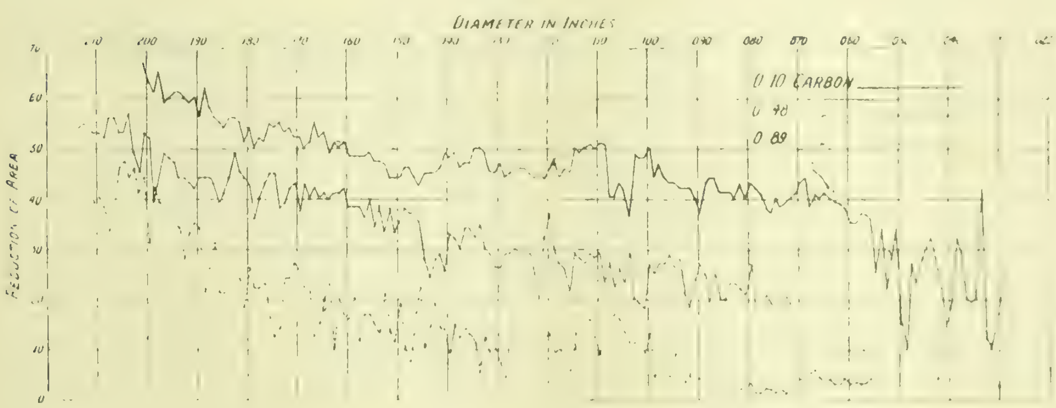


FIG. 2.

The levelling up at each annealing stage is worthy of note, and in the stages indicated drawing may be readily carried down to 34 gauge. Wires of this composition possess a higher permeability for magnetism than pure commercial iron.

Electrical resistivity is also increased by the presence of silicon and aluminium, a fact of value in stifling eddy currents and consequent loss of power to the magnet. A typical resistivity value of steel No. 4 in 5-gauge rolled rod is 40 microhms per cubic centimetre. This value is lightly increased by cold work, and the finished wire will vary from 43 to 45 microhms specific resistivity.

III.—In commercial wire-drawing and cold-rolling practice the steels employed range in carbon from traces to about 1·6 per cent. The higher ranges are usually limited to crucible steels, and, according to carbon content, the drawn wire is fashioned into dental or surgical instruments, hand or machine sewing needles, sensitive springs, fine tools, &c. The properties required in the wire are, ease of machining, allowing ready manipulation into final form. The properties required in the finished articles are essentially those imparted by the presence of carbon, that is, keen cutting edges, penetration, spring and elasticity in the tempered condition. These features give rise to an important difference in drawing practice in that crucible steels are always drawn by comparatively light draughts and with frequent annealings. This results in comparatively low tensile values being reached during the drawing stages, cold work not being carried so far as in the case of mild Siemens or Bessemer steels. A further point arises from the fact that steels containing appreciable free cementite must of necessity be worked down in easy stages. This will be referred to later. For the present it is well to note that with high-carbon crucible steels, two features demanding care are: (1) The avoidance of superficial oxidation. (2) The avoidance of a precipitation of free carbon.

Surface oxidation of carbon is important, for under these conditions it is obvious that the requisite surface hardness will not follow quenching. On the other hand, when cementite has been decomposed into free carbon and ferrite, the wires will not go through later automatic processes with regularity. For example, in needle pointing, those wire lengths containing graphite wear down with great rapidity as compared with lengths free from graphite. Hence, on assembling, variation in length is found, and the short lengths are invariably graphitic.

A series of crucible carbon steels were prepared and put through the usual wire-drawing processes applicable for this class of steel. The analyses are:—

	Steel Nos.					
	5.	6.	7.	8.	9.	10.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Carbon	0·10	0·26	0·75	1·07	1·22	1·47
Manganese	0·11	0·25	0·21	0·24	0·31	0·31
Silicon	0·056	0·041	0·100	0·115	0·061	0·061
Sulphur	0·023	0·022	0·020	0·019	0·023	0·023
Phosphorus	0·026	0·024	0·019	0·022	0·019	0·019

An examination of the tensile results obtained during the various operations illustrates the effect of comparatively steady flow on a series of ascending carbon steels. These results may be summarised as follows:—

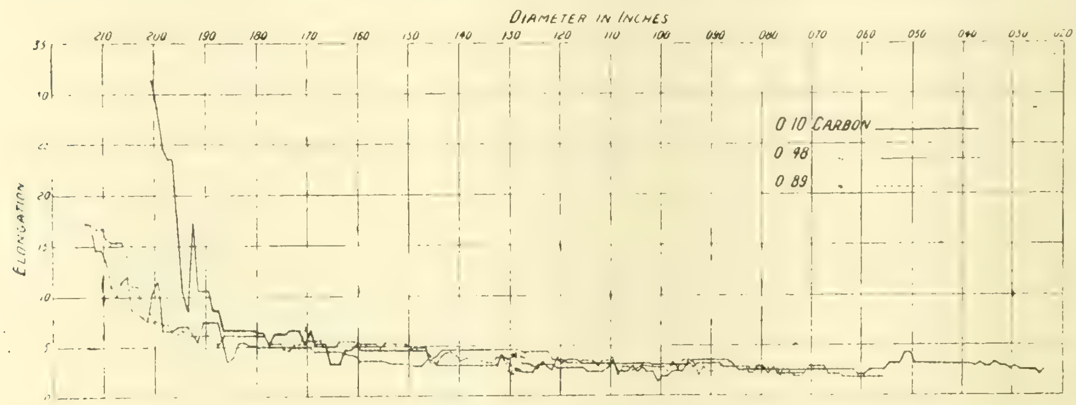


FIG. 3.

Condition.	Carbon, per cent.	Maximum stress, tons per sq. inch.	Elongation per cent. on 2 inches.	Reduction of area per cent.	No. of Twists one way until broken.
Rolled rod	—	23·0	38·0	73·33	35
Annealed rod ..	0·10	21·0	43·75	81·6	39
25-gauge wire	—	46·23	3·9	—	24
Rolled rod	—	31·0	33·85	57·57	17
Annealed rod..	0·26	24·0	36·9	72·8	37
25-gauge wire	—	46·23	3·9	—	42
Rolled rod	—	50·5	16·7	36·8	6
Annealed rod..	0·75	35·0	25·9	59·7	23
25-gauge wire..	—	52·14	4·8	—	32
Rolled rod	—	62·73	9·85	14·8	3
Annealed rod..	1·07	39·75	25·0	51·73	20
25-gauge wire..	—	60·0	5·0	—	30
Rolled rod	—	53·78	13·9	14·8	5
Annealed rod..	1·22	41·0	15·2	51·73	16
25-gauge wire..	—	60·0	6·0	—	32
Rolled rod	—	56·4	4·15	14·8	2
Annealed rod..	1·47	41·75	10·75	14·8	8
25-gauge wire..	—	60·0	7·5	—	22

From 0·75 per cent. carbon onwards the maximum stress values do not differ materially from those of the rods as rolled. However, the comparison should be made against the annealed rods, and the difference is then more marked. In the high-carbon ranges the greater number of twists in the finished wire is noteworthy.

IV.—The exhaustive researches of Beilby show that the polished surface of a specimen of metal indicates that it has passed through a state in which it has possessed the mobility of a liquid.* The skin of a drawn wire, *i.e.*, that portion which has been in actual contact with the "bearing" of the wortle plate, exhibits certain evidences of polishing action. From a very close study of this surface effect the author reaches the conclusion that the analogy with the mobility of a liquid cannot be sustained. There is certainly room for wider and more detailed investigation, but, so far as the work has been carried as regards both skin and core effects, the conclusion reached is that the initial crystalline entity is never lost by cold work. So far as a fairly extensive experience goes, the perfectly vitreous or non-crystalline form has not yet been reached by cold work in the form of drawing or rolling.

Up to a certain point the microscopical examination of cold-worked sections is satisfactory, but beyond this point it completely breaks down. This aspect has been well expressed by Ewing in the May lecture before the Institute of Metals, 1912: "We want to know what are the ultimate particles of which a metal is composed, how these particles are arranged, and why they so arrange themselves. To these questions the microscope is unable to give us anything like a complete answer, and when we attempt to penetrate beyond the region in which we can accept it as a guide, we do so only by the help of such light as may be perceived by the eye of the scientific imagination."

Ignoring for the moment ultimate structures and limiting the discussion to microscopically visual crystalline effects, the first feature of interest lies in the readjustment of structure at each annealing. Although heat treatment heals the effect of cold work, it must be noted that the crystals do not regain their original size, and that in spite of the frequent annealings there is a steady "fining" of the structure as the wire decreases in diameter.

The crucible steels Nos. 5 to 10 have been closely examined at each stage of drawing and annealing, and the following notes are condensed from this examination and from the examination of other series. Steel No. 5, carbon 0·10 per cent., presents in the annealed rod the usual structure characteristic of ferrite, but by the process of flow the crystals are not only compacted and elongated, but also become much finer.

Steels with ascending carbon do not offer points of material difference until free cementite appears. Both pearlite and ferrite flow freely through the dies, but it is questionable whether cementite yields at all. The grains of cementite may be found under certain conditions with their longest axis in the direction of drawing, but the grain itself is not elongated by cold work. High-carbon wires are utilised solely for their ability to take an intense hardness after quenching. When high tensile strength is required, this is reached by suitable manipulation in cold working rather than by high carbon contents.

(To be continued.)

GAS GENERATORS OF THE BLASTFURNACE TYPE.

In gas generators of the blastfurnace type, in which the ashes are fused when using sticky or caking coal, the generator generally works efficiently at the beginning when the fusing is regular, but after a short time the generator shaft becomes cool at the bottom, the slag sets and the fire is confined gradually to the central part and then to the higher part of the generator. The fusing then takes place at a point at which the slag can no longer be taken away and the apparatus has to be stopped on account of the clogging which has

* A summary of these researches is found in "The Hard and Soft States in Metals" ("Journal of the Institute of Metals," 1911, No II).

occurred. This inconvenience is brought about by the fact that while the combustion air and the combustion gases move upwards right through the generator, the coal under the action of gravity travels in the opposite direction, that is to say, downwards. If for any reason such as clogging or an alteration in the working conditions, the fuel does not move down in a regular manner to the level of the tuyeres, the

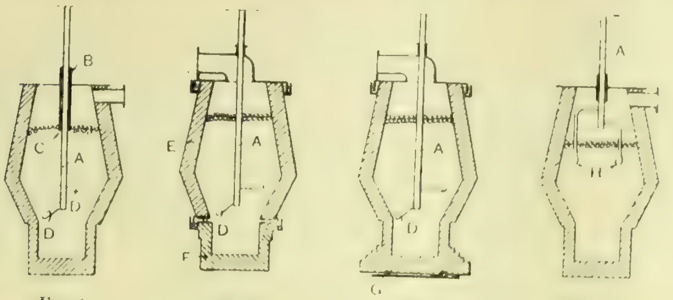


FIG. 1. FIG. 2. FIG. 3. FIG. 4.
BLASTFURNACE TYPE GAS GENERATORS.

combustion air goes up to meet the coal and the incandescent combustion zone rises.

The gas generator illustrated herewith, the invention of the Société des Gazogenes Marconnet, 12, rue de l'Isly, Paris, has been designed to obviate any dangerous clogging or sticking. This is accomplished by combining with an ordinary ash fusing gas generator of the blastfurnace type a mechanical device which breaks up the clogged coal as the clogging takes place. Several modifications of the arrangement are shown diagrammatically in Figs. 1 to 4. In Fig. 1, the gas generator comprises a hollow shaft A mounted in bearings B and C forming part of the cover. This hollow shaft carries one or more fingers D, also hollow, and which are cooled by the water entering and issuing from the hollow shaft. This shaft receives a very slow rotary motion whereby the fingers are enabled to break up the clogged fuel. In Fig. 2, the gas generator also comprises a hollow shaft having cooled fingers, but in this arrangement the shaft is stationary and the casing E of the gas generator revolves on the ash pit F, which is also stationary. These revolving parts carry forward the clogged fuel broken up by coming in contact with the stationary fingers. The whole of the gas generator with its ash pit may also revolve on a track having ball bearings G shown in Fig. 3, but it is also provided with a hollow shaft A having fingers D whereby the cloggings are broken up. These mechanical devices may vary considerably. Another device is shown in Fig. 4, in which the cloggings are broken up by means of slice bars H provided with circulating water and which are mechanically lifted and dropped; in their downward movement they crush the vaulted fuel in the same way as a pestle. In all these devices, it is preferable that the speed of rotation of these agitators should correspond with the volume of the blast, suitable connections being provided for this purpose between the means for driving the agitators and the blast control.

The Use of Reinforced Concrete in Coal Mines.—At a meeting of the Staffordshire and Warwickshire Association of Mining Engineers, a paper was read by Prof. Dixon, Birmingham, on "The Use of Reinforced Concrete in Mines." He emphasized the durability of reinforced concrete, which he described as resisting shock much better than any other material. Its use was coming largely into operation in the United States and Canada. Among other good qualities which it possessed, he mentioned that steel embedded in it did not deteriorate by time or rust.

Fatal Cage Accident at a Colliery.—An accident, resulting in the loss of four lives, occurred at the Silkstone pit at the Newland Collieries, Normanton, on the 18th inst. It appears that 10 persons were ascending the shaft, when a portion of the centre conductor, about 20ft. long and 6in. square, fell from the top of the shaft in a perpendicular manner into the shaft, which is 500 yards deep, and crashed through the upper and lower decks of the cage, the latter of which contained the men. The banksman, noting the fall of the beam, stopped the engine when the cage had only ascended some 70 yards. The cage remained in this position for several hours before it could be released, when it was found that four of the men were killed and two others injured.

PERFORMANCE ON SERVICE OF THE MOTOR-SHIP "SUECIA."*

BY I. KNUDSEN.

IN the autumn of 1911 the Rederiaktiebolaget Nordstjernan Company, of Stockholm, ordered six motor liners from Messrs. Burmeister & Wain, the firm with which I am connected, the dimensions of the vessels being as follows: Length, 362ft.; breadth, 51ft. 3in.; and depth, 34ft.; carrying capacity, 6,500 tons deadweight. The machinery consists of two main engines, each of 1,000 i.h.p. (4-cycle Diesel engines with eight cylinders), besides two auxiliary Diesel engines each of 200 e.h.p. for working the compressors, auxiliary machinery (such as winches and steering gear), and for the production of the electric light; the machinery is in other respects similar to that of the "Selandia," which was described by the author in a paper read before this Institution last year.

As to passenger accommodation, there are only eight cabins for first-class passengers, which is much less than is provided for in the "Selandia;" the cabins, however, are roomy and modern, and provided with bath and toilet rooms. Further, there is ample saloon accommodation, and a hospital. The "Suecia" is intended for the Sweden to La Plata service, and she will be chiefly employed for cargo purposes, being fitted with the most modern loading and discharging gear, such as double derricks and double winches.

The vessel was launched on November 2nd, 1912, and the trial trip took place on December 17th, 1912. The next day

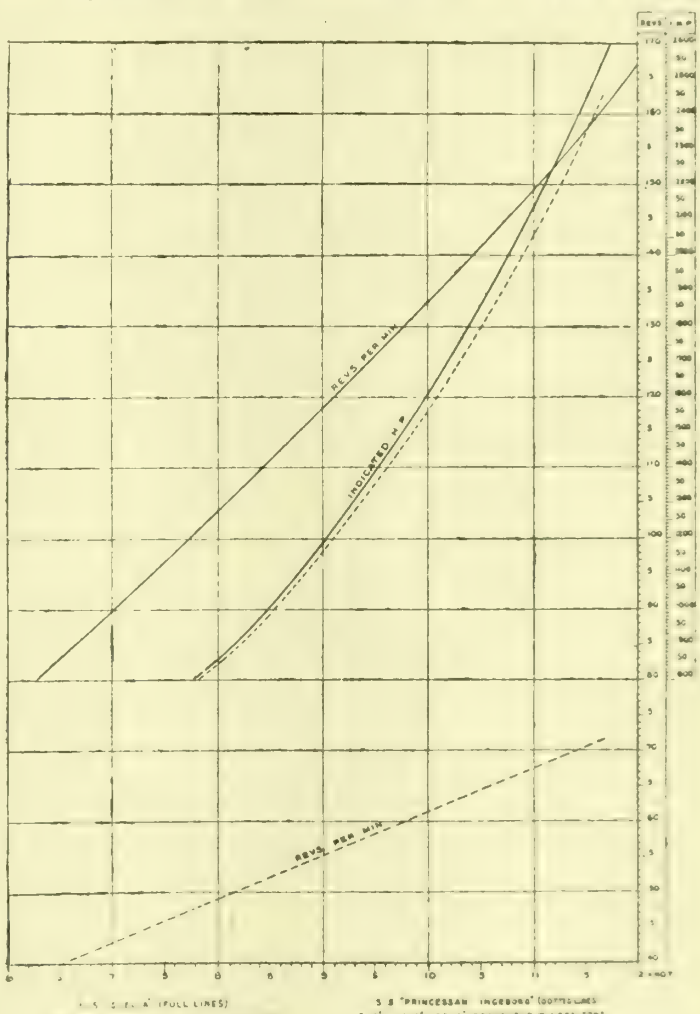


FIG. 1.

she went to Limhamn, where she took in a cargo of 15,000 barrels of cement, then she sailed to Stockholm, where—as far as I know—cargo of 4,000 tons was taken in. On December 23rd she left for Gothenburg, and here she took in still more cargo, and left on December 31st, arriving at Christiania on January 1st, where her cargo was completed, and on January 4th a trial trip took place in the Christiania Fjord with the

* Paper read at the Summer Meetings of the Fifty-fourth Session of the Institution of Naval Architects, June, 1913.

vessel fully laden. When the trial trip had been completed, she went to London, where she arrived on January 9th, and went from London to Rio Janeiro, arriving at that port on February 1st.

I will refer to certain matters concerning the "Suecia" owing to some remarks made in the discussion of the paper which was read before the Institution of Naval Architects, to the effect that no information was given with regard to the efficiency of the propellers, &c., compared with that of ordinary steamers. The reason why no such information was given in connection with the "Selandia" was, that with this vessel, no trial trip took place with the ship fully laden, and consequently we possessed no comparative results. With the "Suecia," however, we succeeded in carrying out this trial trip in Christiania Fjord, and I am glad to have this opportunity of publishing the results.

The full lines on Fig. 1 give the curves showing the indicated horse-power, the number of revolutions, and the speed obtained with the "Suecia." The dotted lines on this figure give similar particulars obtained with the "Princessan Ingeborg," a vessel built a few years ago for the same owners, but fitted with steam engines. As appears from the dimensions given on these diagrams, the vessels are almost alike, both in dimensions and also with regard to the fineness of lines. If the two vessels are compared, it will be seen that to obtain the same speed for the same displacement the same indicated horse-power is required, whether it is to be used in the motor-liner or in the steamer. According to this result, there seems to be no difference in the power required to propel a vessel, whether this is effected by means of a single, large, slow-running propeller, as in the steamer, or by two relatively fast-running small propellers, as in the motor-liner. The

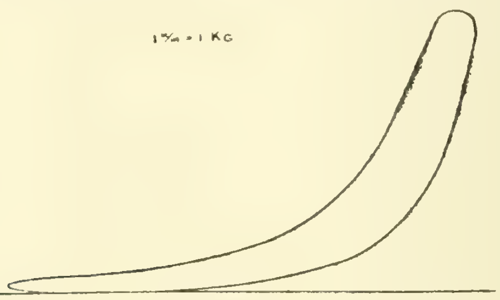


FIG. 2.

propeller in the steamer has a diameter of 17ft. 6in., and in the motor-liner of 10ft.

In this respect it must be remembered that in the "Suecia" the main Diesel engines do not work the pumps, nor the two first stages of the air compressors. The relation of the indicated horse-power to the brake horse-power of the engines will, therefore, be about the same as in a steam engine, and the combined efficiency of the mechanism of the engines and of the propellers is about the same as obtains with the steam engine.

The weight of steam installation in the "Princessan Ingeborg" brought up to correspond with the horse-power of the motor installation amounts to 570 tons, as an extra main boiler was fitted in view of the cleaning of the boilers. The total machinery in the motor-ship "Suecia" weighs 470 tons. With regard to the space occupied by the engines in the "Suecia," this is 41ft. of the length of the vessel, whereas it is 66ft. in the "Princessan Ingeborg," although the horse-power, as stated above, is less in this vessel.

It should be stated that the trial trip took place under good conditions, such as fine weather and deep water. The vessel, however, has now returned from her maiden voyage, and from the speed attained on the Atlantic, the comparative trial trip results seem to hold true in the practical performance of both vessels. In the trial trip in Christiania Fjord the oil consumption per indicated horse-power hour was measured, and a result was obtained which no doubt is the best hitherto obtained, viz., 134 grams of oil per indicated horse-power hour, measured on the main Diesel engines, and when everything is allowed for, such as the consumption of the auxiliary engines, &c., the oil consumption per indicated horse-power of the main Diesel engines amounts to 154 grams, including the fuel oil necessary for the working of the auxiliary engines, steering engines, pumps, &c., but exclusive of the oil used for heating the vessel.

The mechanical efficiency of Diesel engines of the type used, but with the whole of the compression of the air necessary for fuel injection performed by the engines themselves instead of by auxiliaries, has been shown by bench trials to be 80 per cent., so that the oil consumption per brake horse-power of such a marine Diesel engine would amount to 167½ grams per brake horse-power. The diagram (Fig. 2), which was taken during the trial trip, shows by its shape and appearance that the engine is extremely economical.

The "Siam," which we recently built for the East Asiatic Company, was, until now, the biggest sea-going motor-liner, her length being 410ft., her carrying capacity, 9,200 tons, and the horse-power 3,000. It may, perhaps, be of interest to follow the development of motor-liners, and I may add, therefore, that at present the following vessels have been ordered from my firm, besides those already delivered. One motor-liner similar to the "Siam," 410ft. long with engines of 3,000 h.p. for the East Asiatic Company. Five motor-liners referred to above, similar to the "Suecia," for the Rederiaktiebolaget Nordstjernan. One vessel, 405ft. long, carrying capacity 7,500 tons, with engines of 2,500 h.p. for the United Steamship Company, of Copenhagen. To replace the "Fionia," which was sold to the Hamburg-America Line, we are constructing for the East Asiatic Company a motor-liner, 390ft. long, with engines of 4,000 h.p. This company has also ordered from us four other vessels, each with a length of 410ft. with engines of 4,000 h.p. All the figures given of the horse-power are exclusive of the auxiliary Diesel engines.

INDUSTRIAL AND TRADE NOTES.

Light Railways.—The Board of Trade have recently confirmed the under-mentioned Order made by the Light Railway Commissioners: North Lindsey Light Railways (Amendment) Order, 1913, amending the North Lindsey Light Railways Orders, 1900 to 1911, and for other purposes.

German Motor Vehicle Industry.—An official return has just been issued giving the results of the German census of motor vehicles and craft of all kinds for 1911. The numbers of vehicles, &c., produced during that year were as follows: Motor cycles, 3,901; motor tricycles, 1,079; complete motor vehicles for passengers, 10,319; complete motor wagons, including vehicles for special purposes, 1,373; complete chassis, 5,247; complete motor boats, 290; motors, 3,694 (of which 872 were for motor cycles, 1,399 for motor cars and wagons, 787 for motor boats, 198 for flying-machines, and 438 for other purposes). The total value of the output, including repairs and the furnishing of spare parts, amounted to over eight million sterling.

Trade Circulars.—We have received from the following firms trade circulars and price lists as indicated. J. Kay & Sons, Ltd., 93, High Holborn, London, oil lamps and oil cans of every conceivable variety. The Amercian Brass Company, Ansonia, Conn., U.S.A., particulars of physical properties and uses of Tobin bronze. James Keith & Blackman Company, 27, Farringdon Avenue, London, E.C., particulars of the Keith system of high pressure gas lighting for the illumination of workshops, &c. The Schniewindt Electric Company, 41, Stainforth St., Birmingham, electric hot plates for industrial, domestic, and scientific purposes. General Electric Company, 67, Queen Victoria Street, E.C., fuses, magneto mining telephones, &c. London Emery Works Company, Tottenham, London, N., particulars of foundry moulding and coremaking machines.

Self-contained Arc Welding Plant.—The Parsons Motor Company, Ltd., Town Quay, Southampton, have secured an order for a self-contained arc welding plant for a firm of engineers and ship builders on the Continent. The whole plant is self-contained, and can be placed where required. The engine is a 28 h.p. four cylinder standard pattern Parsons paraffin type, fitted with magneto ignition and patent timing drive, and enclosed sensitive vertical-type governor driven by enclosed gears at the forward end. The efficiency of this governor is such that the speed is regulated within 1·05 per cent. The water is circulated by a Parsons pump at the forward end of the engine. The fuel is carried in the tank situated above the engine gravity feed. The dynamo is coupled direct to the engine, and has an output of 250 amperes at 65 volts.

Glasgow Electrical Exhibition.—The electrical exhibition which is to be held this year under the auspices of the Glasgow Corporation will be located in the Zoo Buildings, New City Road. Th exhibition will open on October 23rd and continue until November 15th. It will be devoted to purely electrical appliances, and will be the first enterprise of the kind in Glasgow. Already a large number of stands have been engaged by leading firms. In addition to the display of appliances many interesting

features will be introduced. A commodious hall will be erected inside the buildings, and will be utilised for showing, by the aid of the cinematograph, the latest developments in the use of electricity. Lectures will be given on subjects related to the aims and objects of the exhibition, and there will be demonstrations daily on cooking, baking, &c.

Automatic Weighing Machine for Coal, Ore, &c.—Messrs. W. & T. Avery, Ltd., Soho Foundry, Birmingham, are exhibiting at the Mining Exhibition, Agricultural Hall, an automatic weighing and totalising machine for use in connection with conveyors. The principle of the machine is to weigh a constant length of the conveyor at intervals of time corresponding to the speed at which it travels. The machine exhibited deals with 100 tons per hour with buckets which carry 2 cwt. with an accuracy which meets with the approval of the Board of Trade. As the material conveyed on the weighing buckets leaves the weighing portion of the weigh-bridge, it is registered and totalled on a counter visible at the end of the machine. The motive power necessary to operate the totaliser is taken from the working of the conveyor; it can thus easily be seen that quick or slow weighings can be totalled with equal accuracy. The machine can be arranged for belt conveying as well as by bucket, and it is quite obvious that an immense saving in time is effected while accuracy is guaranteed.

A Successful Premium Bonus System.—Mr. Thomson, of Messrs. David Rowan & Co., Glasgow, in the course of a recent speech, described the working of the premium bonus system which, he said, was instituted at their establishment after the strike of 1898, and which had met with unqualified success. At first their great difficulty had been to gain the confidence of the men and to get them to believe that, having once set a standard time for a unit of work, they would not go back on it. Their experience was that, as a result of this system, the men did their work in about 65 per cent. of the allotted time. That the system was satisfactory to the workmen as well as to themselves was shown by the fact that the men remained with them, and that they had very few changes in the personnel of the machine department. The men earned much higher wages than they could otherwise obtain, and the system had attracted to their establishment the best class of workmen. It had a steadying moral effect on the character of the men, and this was reflected in the quality of their work. During the 14 years in which the system had been in operation the bonuses earned by the men employed in the engine works amounted to no less than £47,000. The amount paid last year was £4,700. He believed that if the system was generally adopted it would tend to ameliorate and lessen labour troubles.

The Packing of Machinery for India.—In response to an enquiry on the subject the Director-General of Commercial Intelligence, Calcutta, writes that the chairman of the Bombay Port Trust has made personal investigation regarding the breakage of cases of machinery consigned to that port. After viewing a large number of cases damaged and undamaged the chairman of the Port Trust formed the opinion that damage was mainly due to three causes, viz.: (1) Insufficient iron strapping of heavy cases; (2) improper slinging; (3) insufficient thickness of cases to withstand heavy weights stowed over them. The chairman of the Port Trust considered that the first was a very fruitful cause of damage. The second he considered to be less important, while the third frequently results in dented cases with damage of the contained machinery, if delicate. The Director-General of Commercial Intelligence remarks that he inspected a large number of cases of machinery landed at Bombay from two steamers. A certain number of cases were broken; but almost all were long cases which showed signs of having been bent by their own weight either in slinging or through being placed on a short trolley. Some scores of cases were inspected, and the impression gained was that the cases broken were barely strong enough for their weight and long form, having regard to the fact that they had probably to be handled several times between the works and place of delivery.

Geared Turbine Vessels.—An experiment of interest to engineers is to be tried by the Anchor-Brocklebank Line, who have placed an order with Messrs. Charles Connell & Co., of Scotstoun, for two steamers, each 470ft. in length, 58ft. in breadth, 35ft. in depth, and of about 7,500 tons gross. The vessels are to be sister ships, so far as design of hull, boilers, and propellers are concerned, but while one is to be propelled by triple-expansion engines, the machinery of the other will consist of Parsons turbines geared down by means of Parsons helical reducing gear. Both will be single-screw. The reciprocating engines will run at a speed of 80 revs. per minute, while the speed of the turbines of the sister ship will be 1,500 revs. per minute on the turbine shaft, reduced by means of the gear to 90 revs. per minute on the propeller shaft. The owners propose to run the vessels on the service between Glasgow, Liverpool, and the East, under as nearly as possible similar conditions, so that their performance should furnish valuable data regarding the respective merit of the two types of engines. The large Cunard steamer "Transylvania," now under construction at the yard of Scotts' Shipbuilding and Engineering Company, Greenock, is also to be propelled by turbines and Parsons reducing gear. This vessel will be twin-screw, 550ft. in length, 66ft. in breadth, 45ft. in depth, and of about 15,000 tons gross. Another large vessel which is under construction on the Clyde for geared turbines on the Parsons system is the liner which Messrs. Alexander Stephen & Sons, Linthouse, are building for the Anchor Line. This vessel is to be twin-screw, of almost the same general dimensions as the "Transylvania."

A Heavily-taxed Industry.—At the 46th ordinary general meeting of the shareholders of the Ebbw Vale Steel, Iron, and Coal Company, held in London on the 17th inst., Mr. Joseph Bradford, the chairman, said the gross profits for the year amounted to £184,108. The available balance of profit was £159,590, from which had to be deducted expenditure on new works, £23,423. They proposed to apply in reduction of outlay in suspense account £50,000, and they recommended a dividend of £1 per share, being at the rate of 10 per cent. for the year, which would absorb £74,475, leaving a balance to be carried forward of £11,692. Wages amounted to £933,670, an increase of £186,213. Wages in their collieries had been raised from $51\frac{1}{4}$ per cent. to 57 per cent. above the standard of 1879, and there was an increase of $2\frac{1}{2}$ per cent. which came into operation on June 1st, which raised the colliers' rate of wages 60 per cent. above the standard, which was the maximum amount. In the iron and steel works there had been a rise from $10\frac{3}{4}$ per cent. to $25\frac{1}{4}$ per cent. above the standard. The rates of the Ebbw Vale Urban District Council now amounted to 11s. 4d. in the £, and they had achieved the unenviable distinction of being the highest rated in the United Kingdom. The company paid about three-fourths of these rates, and they had no voice in the representation of the Council. Local rates amounted to £32,003, workmen's compensation came to £17,599, and National Insurance—for nine months to £4,755. The items made a total of £54,357, an increase in the three items of close on £10,000. In addition they had had to pay Imperial taxes in the shape of duties and income tax £7,904, under the new Land Act £12,000, which was largely initial outlay, and there was also heavy expense entailed by the Minimum Wage Act and the Eight Hours Act. Their estimate of the total, with the items he had given, amounted to £74,260. This was practically the same sum as they were proposing to distribute in dividend.

The Waterways Association.—A meeting of this Association, formed with the object of developing the canal traffic in this country, was held in London on the 20th inst. Mr. Neville Chamberlain, the chairman, in moving the adoption of the report, said they had received a repulse from the President of the Board of Trade, who had said that the Association had not told him what prospect there was of a fair and reasonable return upon the capital expenditure, which he pointed out was likely to reach from 15 to 17 millions sterling. Mr. Buxton had also stated that the Government were in no way hostile, but it was mainly a matter of time, opportunity, and practicability. Mr. Buxton, in asking for statistics as to the increased traffic, was, Mr. Chamberlain remarked, asking for what he knew it was impossible to give. How could anybody possibly tell what was going to be the stream of traffic ensuing from conditions which did not exist, and which never had existed in this country? They had never pretended that in their proposals they were to have a new Suez Canal investment. On the contrary, they had always maintained that the benefit to be derived was indirect, and that it would result from the increased prosperity consequent upon the improved facilities and the increased rateable value which would follow upon the establishment of factories along the lines of the canals. Every single foreign country which had adopted the policy of developing its own waterways had thriven and prospered upon it and had been so much encouraged that they were continually spending money upon their waterways. The Association had not asked the Government to spend 17 millions in one block; what they asked was that the Government should form a Waterways Board and acquire the waterways comprised in "The Cross," centralise ownership and do away with the divided ownership which hitherto had been one of the greatest curses of canals. That Board would form its conclusions as to what route, if any, should be improved, and the Government would not be committed to make any of these improvements until they had the report of their own Board. Mr. H. Terrell, K.C., moved a resolution urging the Government to take immediate action upon the report and recommendations of the Royal Commission on Canals, which recommended the appointment of a Waterways Board and the acquisition by the

State of the four trunk or main canal routes, referred to as "The Cross," the Waterways Board acting as the controlling authority, to be toll takers, not carriers. He urged the institution of a campaign to create and concentrate public opinion on the question. The resolution was adopted.

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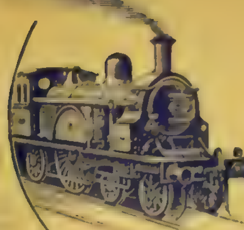
The Mechanical Engineer.

Friday, June 27, 1913.



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Vol. XXXI.
No. 805.

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